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ABSTRACT

This report of a 1969 Environmental Sciences Institute includes presentations from authorities on environmental problems, the discussion following some presentations, references, and the results of a panel discussion which involved all conference speakers. Papers presented were: "Is There an Ecological Crisis?" "The Challenge of Environmental Quality," "Man and the World Ecosystem: How Many More People Do We Want?" "Radiation and the Energy Budget of Organisms," "Remote Sensing of Water Pollution," "Interactions of Certain Atmospheric Pollutants with Lung Tissue," "Pesticide Kinetics in Ecosystems Disturbed by Man," "Controlled Environments for Plants in Research--A Critique, A Contribution and Future Prospects," "Environmental Physiology and Control in Space," "Culture and Subculture as Environment," and "An Approach Toward a Rational Clarification of Environmental Science." (CP)

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PROCEEDINGS *of* CONFERENCE I

MAN *and* HIS ENVIRONMENT:
INTERACTION AND INTERDEPENDENCE

Dr. J.Y. Wang, Ed.
(1969)

Environmental Sciences
Institute
125 South Seventh Street
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MAN AND HIS ENVIRONMENT:

INTERACTION AND INTERDEPENDENCE

Dr. J.Y. Wang, Editor

San Jose State College
San Jose, California
1969

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FORWARD

Early in 1969, the Environmental Sciences Institute organized an annual conference series around the theme of MAN AND HIS ENVIRONMENT: INTERACTION AND INTERDEPENDENCE.

The occasion of the first conference was held in conjunction with the dedication of Carl D. Duncan Hall in honor of the late Dr. Duncan for his role in educating students and citizens about the vital issues of man and his environment. He taught in the fields of entomology, science education, and conservation at San Jose State College for 43 years. He was the first to offer a course on "Man and the Environment," and was an outspoken leader on the need to curb our exploding population.

The first conference, which was held on May 28-29, was concerned with the general aspects of environmental problems. These include problems of ecological imbalance, environmental quality, population explosion, water pollution, cultural pollution, risks of air pollution weighed against cost of protection, species extinction resulting from pesticide residue in the ecosystem, and food production improvement through controlled environmental techniques. Related areas also extend to the most basic environmental process for animal and plant life. This process is the mechanism of the exchange of energy between organisms and their physical environment. All of these loosely-related presentations, considered together, illustrate the variety and the complexity of the problems which man faces. The major prupose of this conference was to focus upon several of the scientific and technological dimensions of the ecological and physical relationships between man and his environment.

For this conference, many national and international scientists were invited to present their up-dated and unpublished findings. Their presentations are published here, together with each author's position and address, a summary of their articles, the floor discussion, and references. A panel discussion concluding the conference which involved all of the speakers is included in

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this publication, and an article entitled "An Approach Toward a Rational Clarification of Environmental Science" has been especially prepared in order to emphasize the total environment concept which embraces the theme for future conferences on man and his environment. Exhibitions of books and instruments were offered concurrently with the conference and the names and addresses of exhibitors to such are listed at the end of this publication.

Sincere thanks are extended to staff members and students of San Jose State College for their financial and moral support towards the success of this conference. Others who deserve special mention are Dr. David G. Barry, Executive Vice President; Dr. Matthew F. Vessel, Dean, and Dr. H. Thomas Harvey, Associate Dean of the School of Natural Sciences and Mathematics; Dr. Robin Brooks, Associate Professor of History; Mr. Keith C. Cluckey, Assistant to the President; Mr. James E. Noah, Director, and Mr. Jack McCleneghan, Assistant Director of Public Relations and Publications, all of San Jose State College; and Dr. John E. Greenleaf, Research Physiologist, NASA-Ames Research Center. All of the above-mentioned persons served with the editor on the Executive and Arrangement Committee. Among these, Dr. H. Thomas Harvey must be recognized for his tireless efforts in coordinating this conference. The National Science Foundation, the Loma Prieta Chapter of the Sierra Club, the Santa Clara Valley Audubon Society, and the Associated Students of San Jose State College have generously supplied the funds to make this conference possible.

We are grateful to all of our speakers, participants, exhibitors, and particularly to Mr. Fred Siemon, Chief of the Science and Technology Department of San Jose State College Library, for their interest and enthusiasm for the program.

The subsequent annual conferences will deal with more specific areas such as environmental education, including behavioral science; modern environmental systems; socio-economical imbalance; and technological developments in the conquest of hunger.

J. Y. Wang, Editor
November, 1969
Environmental Sciences Institute

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IS THERE AN ECOLOGICAL CRISIS?

H. Thomas Harvey, Professor
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SUMMARY

To consider less than the world when questioning the health of the ecosystems of which man is a part is, to say the least, short-sighted. However, let us deal with what is going on in this state; this Bay Area; this county; this city; from the ecological point of view, realizing, as we do, that each is merely a part of the greater whole.

Owing to man's unique capacity for rapid cultural change through the manipulation of his environment with technological sorcery, many wonder if his biological systems, both physiological and psychological, can keep pace. Can we evolve to tolerate increasing pollution and will we be happy doing it?

There are increasing bits of evidence that our environment is being interacted with in such a way as to produce direct, hazardous conditions for man. There are also increasing indications to suggest that there may be subtle, indirect hazards to the health and welfare of mankind. Apparently, DDT, in concentrations of a few parts per billion of water, depresses the oxygen production of some oceanic diatoms. Most of the oxygen we breathe here in San Jose probably comes from the oceanic diatoms; and toxins that adversely affect these diatoms flow out the Golden Gate into the ocean; this should, therefore, be of much concern to us all.

Loss of shallow waters of the San Francisco Bay and the adjacent salt ponds would decrease, in proportion to the amount destroyed, the quality of our environment. Presently these areas ameliorate our climate so that smog is reduced, provide educational and aesthetic values for many, serve as reservoirs for wildlife which provide hunting and fishing, assimilate our sewage (shallow waters only), and serve as a potential source of food, now rendered unusable by pollution.

If we accept as one of the highest moral obligations the preservation of human lives, then it follows that if we are responsible for changes in the environment which destroy life, we are obligated to do something about them. The role of the scientist is to inform the citizens and public leaders of the alternative solutions to our growing environmental problems.

WHAT IS THE ECOLOGICAL CRISIS?

If there is an ecological crisis, what is it? How did it arise? And what can we do about it? There seems to be little doubt that the tremendous population explosion of man has upset the interrelationship of living things and their environment, including man himself. Destruction of salt marshes around the San Francisco Bay has greatly reduced oxygen production, endangered wildlife, and increased pollution. Increased temperatures in the Columbia River due to dams and nuclear reactors have aided a formerly rare, but deadly, bacterial fish disease to flourish in recent years and, thus, threaten the famous salmon runs. Persistent pesticides are found worldwide and, as they build up in concentration in the food chain, they threaten various wild species with extinction. The oil slick at Santa Barbara; the increasing smog in our evermore congested urban areas; the rising rate of emphysema --- all these events and many more are but threads in the fabric of disaster.

When non-scientists exclaim that "things aren't too bad and, besides, science will solve the problems of population and pollution (popullution)," I wish they would take a look at who is showing the grestest concern over this ecological crisis: It is the scientists themselves!

Although the present picture is none too good, consider what is planned for our beleagured spaceship earth. The anticipated future development of the Columbia River could raise the temperature above maximum levels that may be tolerated --- even for a few short hours --- by salmon and steelhead.[1] The vast State of California Water Plan would reduce the flow of fresh water into the San Francisco Bay to the extent that it may become the Lake Erie of the West. Plans exist for filling in thousands of areas in the Bay, particularly in its shallow waters and salt ponds. Noise pollution will become so great if the SST and Concorde are allowed to fly over land that people will not be able to withstand the beating to which they will be subjected.[2] There is not only a serious ecological crisis at the present, but most signs point to an even greater deterioration of our environment in the all too near future.

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[1] Strand, R. H. and P. A. Douglas, 1968, "Thermal Pollution of Water," S.F.I. Bulletin, No. 191.

HOW DID IT ARISE?

When we arrive at the question of which guidelines we should follow if man is to continue to live on this earth, we are forced to consider the principles of ecology. These principles involve concepts of limits to population, carrying capacity of the environment, stability of the community of life, and many more considerations. Just why is the question of the future of mankind an ecological phenomenon? That is to say, how did we get into this mess in the first place? We have gotten into this crisis because of the basic fact that we are consumers and that we produce wastes. The faster our population grows and the "faster" we live, the more consumption and production of wastes occurs. Man's biological capacity to produce eight to ten offspring per family is fundamental to our dilemma. It is an evolutionary fact that only by producing more offspring than the environment could support did early man manage to survive. But, now with death control and very little birth control, we are in trouble over the demands we are making on our environment.

It may be helpful at this point to recognize the basic unit of study in ecology, namely, the ecosystem. An ecosystem is generally recognized as the biotic community (all living things in a given area) and the surrounding abiotic factors, i.e., the physical environment. A pond, a forest, or the entire surface of the earth (the ecosphere) may be the ecosystem under study by an ecologist. An ecosystem may have outside sources of energy, nutrients, and biota (input) to the system under study as well as output, but the pond or forest may be analyzed as a natural dynamic system. Man and his environment also interact to produce an integrated system. The question, then, is what do we know about the persistence of certain ecosystems, particularly those involving man?

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[2] Kryter, K. D. 1969, "Sonic Booms From Supersonic Transport," Science, 163: 359-267.

This brings us to a consideration of the ecological phenomenon of succession.[3] Successional patterns are not fully understood and some differences of interpretation exists between ecologists; but basically, one ecosystem in a given area is replaced by another without any external force or factors affecting it. The biotic community produces physical changes to the ecosystem such that the original community is unable to survive. That is to say, when succession occurs, certain species produce conditions which they and their associates can no longer tolerate. Although we speak of it as one community replacing another, it is generally recognized as a continuum, with potentially forward as well reversed replacement. Finally, under a relatively stable climate, a community is established that does not eliminate itself; it is termed the climax community. For example, on the middle slopes of the Sierra Nevadas the white fir forest with its attendant shrubs, herbs, and animals is situated. If fire comes through the area and destroys the forest and there are a few giant sequoias in the area, they will be favored by the conditions of the fire and dominate the area for centuries to come. However, as they reached 200 to 300 feet in height, they would shade the forest floor, drop so much litter that duff 5 to 6 inches would accumulate; these conditions, in the main, would prevent any significant reproduction to take place.[4] These same conditions, however, do not prevent white firs from reproducing and growing, so that eventually the sequoia forest is replaced with the white fir, provided that fire does not again sweep through the area. Let it suffice to say that past natural wild fires have played a major part in selecting the present attributes of the giant sequoia. Its thick, somewhat fire-resistant bark, the fall of hundreds of thousands of seeds per year, and its intolerance of shade all appear to fit it for survival, reproduction, and growth. Therefore, the fir forest, as a climax community, is a stable and perpetuating system which is only altered by dramatic disruptions such as fire, windfalls, or logging. The natural tendency, then, is succession toward a stable climax community. According to Odum,[5] such successional processes as outlined above have certain attributes in common. Of interest to us in considering the ecological crisis facing mankind is the recognition that homeostasis with the environment is the "strategy" of succession. That is, the stable ecosystem is one in which the climax community has reached equilibrium with the environment. Odum contends that man's goal is maximum production, while, in contrast, the climax community is one which has reached maximum biomass and interdependence, but remains at a low productivity level. Thusly, he suggests, man is in conflict with a basic biological phenomenon --- succession.

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[3] Odum, E. P. 1969, "The Strategy of Ecosystem Development," Science: 164:262-70.

[4] Hartesveldt, R. J. and H. T. Harvey, 1967, "The Fire Ecology of Sequoia Regeneration," Proc. Calif. Tall Timbers Fire Ecol. Conf.

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WHAT MAY BE DONE ABOUT IT?

Well, what can we do about it? The major question being raised is what can man do to bring stability to the communities created by him? It should be apparent that the world is finite and that, eventually, man's exploding population will be controlled either by design or disaster. Humane efforts must prevail, or the ancient subhuman limitations of population by disease, starvation or predation will! (And the predation I fear, is self-predation.)

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[5] Odum, op. cit.

The major change must be a change in attitude. As Garret Hardin points out, the question "what shall we do about the crisis?" is not a technological question and the answers are not to be sought in technological terms. But, rather, we must alter our assumption that we are dealing with a crisis that has a technical solution. We must, instead, face up to the fact that we must either change our attitude or our value judgments, or man -- as we know him -- is doomed. He put it well when he stressed that only through "mutual coercion, mutually agreed upon" are we likely to give up the basic pathological freedom to produce offspring.[6] Either we give up some of our freedom to breed or we will be forced to give up other, more precious freedoms such as the freedom to breathe, the freedom to eat, the freedom to hear, and finally the freedom to live.

In a recent article in Science, Garrett Hardin suggests that the goals of our society must be re-examined in the light of the tragedy of the commons.[7] This concept is based upon the relationship of rational herdsmen who keep as many cattle as possible on the common pasture. This is a satisfactory arrangement as long as the herds are well below the carrying capacity of the commons. When human population increases in density, each herdsman seeks to maximize his gain by adding one more cow to his herd. Each additional cow, however, depletes the resources available to all the cattle by only a small fraction for each cow. Each herdsman may think he has gained a cow, but the tragedy is that everyone loses a little. Because there are available consumers, the herdsmen add another animal to each herd and another; and another; and another, until the commons is ruined for all. Resources are finite as the world is finite.

The problems of pollution are, in a reverse way, also a tragedy of the commons. Instead of continually removing more and more from the finite world as resources, affluent societies dump more and more pollutants into the common natural resources of clean water, air, and soil. It is to the short-range economic gain of the few to do so; it is to the long-range ecological loss of the majority who are saddled with polluted water, smog-filled air, and pesticide and waste-clogged land to do so. Succinctly, we must change our attitudes toward the earth.

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[6] Garrett Hardin, 1968, "The Tragedy of the Commons," Science, 162:1243-1248.

[7] Ibid.

The fallacy that because one owns the land he may decide what use he will make of it and has the inalienable right to make money off of it must also be reassessed in the light of the general welfare. A pig farm is not permitted in a residential area and a residential area should not be allowed in the San Francisco Bay. Heyman has reported on this matter, citing several California cases, particularly Smith vs County of Santa Barbara.[8] The court upheld "regulation of private land . . . establishing that an owner of private property could be compelled to forego more profitable uses in order to promote . . . the public's convenience . . . and this without condemnation or compensation for the loss in value."

We must change some of our basic attitudes toward the world around us. Foremost is our belief that only as a region grows in population is it going to gain economically. In the short view, this may be true; as a long-range strategy, however, it is a fallacy that may destroy the environment and the quality of human life as well. As numbers of humans increase, the pollution of air, water, and soil is presently inevitable and individual freedoms are curtailed. To curb these inroads to a liveable environment, limits must be placed on the numbers of people that can come into an area. This can best be accomplished by wise planning which leaves considerable open space.

The admonition of Aldo Leopold[9] is still the most relevant , general, and ecologically sound concept I know. He declared:

> . . . A land ethic is right when it tends to preserve the integrity, stability and beauty of the biotic commun-

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[8] Heymen, I. M. 1968, "The Great 'Property Rights' Fallacy," Cry California, Summer Issue.

[9] Leopold, A. 1949, A Sand County Almanac, Oxford Univ. Press, 226 pp.

> ity. It is wrong when it tends otherwise. The major problem facing America is not the building of roads into lovely country, but the building of perception into the still unlovely mind of man.

If one ascribes to the thought that human adventure is worth its salt and should be perpetuated as long as cosmically possible, then attention must be paid to the tragedy of the commons, the land ethic, and the stabilization of population in addition to the wise use -- and not abuse -- of natural resources.

To fail to reuse resources from the land rather than to fill the Bay (or Lassen County) with garbage or to bury iron, aluminum, and plastics, in so-called sanitary land fills; or dump our sewage, pesticides, and fertilizers into our waterways is short-sightedness of the first order.

If one turns to a specific area and attempts to assess the Russian roulette played with nature, there are always alarming gaps in our knowledge of the odds. In the geographical region known as Santa Clara Valley, there is presently occurring a population explosion unequalled by most regions of the globe. The human population is gaining at a 4% rate of increase per year.[10] The demands placed upon the environment to assimilate wastes is dimly known. Monitoring stations of air pollution, for example, are few, widely spaced, stationary, and only a few feet above ground level. Thus, all we have, essentially, is a sparse, two-dimensional view of what is happening to our air. We each process about 15,000 quarts of air per day and probably serve as the only abundant and rather efficient air cleaner on the market today. The role of the Bay in stabilizing our climate and reducing our smog can be sketched in broad outlines only.[11] We simply do not know enough details about natural processes to accurately determine what scale of change by man may trigger which responses in nature. The general consensus by those active in the field of inquiry, however, is one of caution and concern derived from application of well-established principles of the various environmental disciplines.[12]

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[10] Carruthers, E. (Ed.), 1968,"Santa Clara County Reaches One Million Population," Santa Clara Valley Plans, No. 50.

[11] Miller, A. 1967, "Smog and Weather: The Effect of San Francisco Bay on San Francisco Bay Area Climate." BCDC Report.

The waters of San Francisco Bay still serve as part of our sewage treatment system. Most of the treatment plants around the Bay still provide only primary treatment. Even those with secondary treatment make considerable inroads on the quality of the Bay waters.[13] Because of the health hazard, about 90% of the Bay is closed to shell fishing and it is estimated that over 200,000 man-days of clamming are thus denied to local residents as well as the loss of recreation in the form of water-contact sports.[14] Although we already know something of the dimensions of our effect upon the environment and its interaction with us, we are still woefully ignorant. Odum[15] suggests that the "preservation of natural areas is not a peripheral luxury, but a capital investment from which we expect to draw interest. Only by setting aside considerable open space will we have a margin of safety until we can determine more precisely how far we may go in expanding intensive agriculture and urbanization."

CONCLUSION

In summary, I wish to use the analogy of the earth as a space ship. Not a bad idea, as we can now vicariously appreciate the hazards of a space voyage. Once the decision is made by the chance fusion of gametes that results in a human life, each of us becomes a member of the crew. Tinkering with the works may lead to disaster just as easily as fighting among the passengers. When the ship is having difficulty it seems strange that time, money, and effort are expended in an attempt to explore distant spaceships (i.e., the moon). It is also peculiar that one portion of the crew is unsympathetic to the disasterous overcrowding of one of the compartments, which, in reality, threatens the entire ship. It is very much like the sinking boat which Paul Ehrlich describes in reference to our population explosion.[16] How unrealistic we are to suggest to the populous have-not nations that their end of the boat is sinking, not ours!

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[12] Gates, D. M. 1968 Introduction in Biometeorology, W. F. Lowry (Ed.), Oregon State University Press, 171 pp.

Harvey, H. T. 1966, "Some Ecological Aspects of San Francisco Bay, BCDC Report.

[13] BCDC Staff, 1967, "Water Pollution & San Francisco Bay," BCDC Report.

[14] Wooster. T. 1969, "Fish & Wildlife Resources of San Francisco Bay & Delta," California Department of Fish & Game Publication TASK VII-1B.

[15] Odum, op. cit.

To end on a positive note is most difficult; yet, many concerned persons continue to work to improve our situation because they share my feeling that it is still better to light one small candle than to curse the darkness. George Wald has recently voiced his concern about the world crisis as students all over the world are beset with a profound uneasiness. I close with his words for they speak so eloquently of both our obligation to a liveable environment and to each other.

> About two million years ago, man appeared. He has become the dominant species on earth. All other living things, animal and plant, live by his sufferance. He is the custodian of life on earth now. It's a big responsibility.
>
> The thought that we're in competition with the Russians or the Chinese is all a mistake and trivial. Only mutual destruction lies that way. We are one species with a world to win. There's life all over this universe, but we are the only men.
>
> Our business is life, not death. Our challenge is to give what account we can of what becomes of life in the solar system, this corner of the universe that is home, and most of all, what becomes of men -- all men of all nations, colors, and creeds.
>
> It has become one world, a world for all men. It is

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[16] Ehrlich, P. R. 1969, The Population Bomb, Ballentine Book Publishing Company, New York.

> only such a world that can now offer us life and the chance to go on.[17]

In order to go on, we must replace the freedom to breed with the freedom to breathe. Our concern must be for the quality of life on earth. Our goal should be to appreciate the gift of life by living in harmony with all men and all other living things.

DISCUSSION

QUESTION:

What effect will barriers have on the ecology of San Francisco Bay?

HARVEY:

A study by Richard Karn on barriers in the San Francisco Bay about a year and a half ago that there did not seem to be a solution for creating the currents and movements of waters which some suggest as one way to handle the pollution problem in the South San Francisco Bay. Dr. Gustafson of San Francisco State College has also proposed two parallel barriers in order to allow the water to come in at one end, flow down to the end of the channel, then open it up so that it will flow down the center of the Bay. I just don't know enough about hydrological feasibility to know whether it would, indeed, work.

QUESTION:

Will the removal of silt improve the quality of the Bay water?

HARVEY:

Well, I attempted to speak about that with reference to what few tests have been made in the north end of the Bay. If water quality was "improved" by removing the silts that come down the river -- but we still dumped in the limiting phosphorous and nitrogen compounds -- then there would be a problem created. In the South Bay, I just don't know of any studies that show just what will be our fate as we reduce the pollutants. Dr. Felice's work at the University of San Francisco indicates that the domestic sewage, although it has a disasterous effect, as it becomes diluted it actually brings about an increased amount of growth, of life. You've got a mixture of factors involved regarding what's going to happen when we stop polluting the Bay with the kind of organic waste that we now dump into it. It is being fertilized by about 300 million gallons per day of sewage. This is yet a problem, largely because of turbidity because the silt load inhibits light penetration and has not produced as of yet a great algal problem. In the South Bay, as I understand the turbidity problem, it's created by the wave action on the soft mud bottom more often that the flow in from the river streams. So, it's a different problem that that of the North Bay.

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[17] Wald, G. 1969. Man's Concern Must be Life, Not Death, Population Reference Bureau, Selection No. 27.

QUESTION:

Can't we treat solid wastes in a better fashion?

HARVEY:

There are a number of proposals regarding this, and perhaps the engineers who are present could answer you. We're planning (Dr. Barry was going to discuss this in his earlier remarks) three conferences, one of which will deal with the technological planning and political solutions or alternatives open to us. As this is not my particular field, I can only mention then off-hand; I think most of you have heard or read of them elsewhere. I would rather some engineer speak on that question

QUESTION:

What can one individual do?

HARVEY:

It starts with each of you changing his attitude and convince others to do the same. It boils down to a philosophical question, and that is do you really think the human adventure is worth its salt? If you don't care, then you're not likely to change your attitude in favor of what's most beneficial for us all; you'll be primarily concerned with your own well-being. This, I think, is a fallacy as exposed by the tragedy of the commons: The belief that if you economically better yourself it will naturally result in an improvement in the economy of the entire society is becoming less and less true. In order to benefit as a small minority one must take from the resources of a greater majority. In the past, the majority hasn't noticed it because competition or carrying capacity of the environment has not been so strained, so the little exploitation of a few is not, then to the detriment of a great number. But, it's beginning to get this way and we need to change our attitudes. I have suggested that this may be forthcoming as court rulings in cases where a municipality has zoned land for levels of use that would not permit the owner to extract a maximum of economic gain because it does not offer the public open space at beaches or airport approches, have ruled in favor of the majority.

You may put houses on land you own, except if the land has been zoned otherwise. These are some of the attitudes that I feel must change if we are truly concerned with the future of mankind.

QUESTION:

Could you predict when the ecological crisis will become acute?

HARVEY:

As I suggested, all ecologists are operating from a few given principles, a few facts which indicate that direction, and then making an educated guess. George Wald adresses this point as well. You really ought to read his article as we have found it so meaningful. He suggests that some ecologists feel it will be in the 1970's. Others feel that we may stave off greater problems until the 80's and maybe until the early 90's. But, very few are optimistic about reaching the year 2,000 before things become unglued. Dr. Raven, I am sure, will expand on it. We here in America seem to have adopted another way to solve our population problem --- that is, to pollute it to death. Natural populations tend to stabilize due to either production of conditions which they can no longer tolerate (the classic example is the bacterial colony which produces toxins which limit its own kind) or putting such a demand upon the resources that they are not available at a rate fast enough to maintain the population. In different parts of the world, man seems to be trying both "solutions" to the population problem. I tend to take the middle ground -- it's the mid-80's.

QUESTION:

Are there any groups working on land use laws of plans of this sort in California?

HARVEY:

There is a plan for the development of the State of California, but it's been proposed and handled largely out of the Department of Finance. I've glanced at it and it does make mention of the tremendous population problem which we're faced with in California. But, I was greatly discouraged when I talked with the Chief Planning Officer for the State of California who indicated that I really shouldn't be concerned about developing specific use for various parts of the state, particularly regarding great open spaces, because the country is way below the density of Asian countries. When he said that, I felt that the problem we must work on is that of changing attitudes.

QUESTION:

Will the entire earth ever become one controlled environmental system?

I would hope so. Again, you see, you must turn to the engineers who are experienced in their fields. From the ecologist's point of view, this is what we are hoping for and it's why we address the point that man must change his attitude about having an open system here on earth. We ARE one world and if we hope to help developing nations by aiding them to become as we are, just think of the problems we will have in deciding what to do with the by-products of an affluent, effluent society. In the final analysis, we must come to an equilibrium. There is no system that can keep accelerating --- NONE! I don't think human society can violate that basic law.

THE CHALLENGE OF ENVIRONMENTAL QUALITY

Keynote speech of the Conference

Werner A. Baum, President
University of Rhode Island
Kingston, Rhode Island

SUMMARY

Deterioration of our physical environment is a result of modern technological advances accompanied by great economic development. This deterioration poses a major challenge to the very survival of mankind. The ominous threat results from the relationships among existing industrial procedures, economic development, and population explosion. These relationships are considered and alternative solutions are explored. An integrated, closed system of total man-environment, requiring contributions from a great variety of disciplines is considered; the concept of "Spaceship Earth" is emphasized. The roles of private producers and consumers, government and universities in developing this concept are discussed.

I did not have the pleasure of knowing Carl Dudley Duncan, in whose honor we are today dedicating a magnificent facility. In his lifetime of service to San Jose State College, he roamed broadly over the intellectual scene, working in entomology, in botany, in science education, and in his later years taking a forthright stand on mitigating the population problem through birth control. With this breadth of perspective he would, I suspect, share the tinge of disappointment I have at the tenor of our discussion during these past two days.

We have been considering small pieces of a problem -- important pieces, to be sure -- without looking at the large picture, without recognizing the broader framework within which the natural scientist must work along with others. Let me present one viewpoint toward that framework.

Our current era of great economic development and unprecedented scientific and technological advance has been accompanied by a critical deterioration of the quality of the physical environment -- atmosphere, water, and earth. This deterioration of the environment may turn out to be the greatest challenge man has yet faced on Earth. In the production and economic development process, modern industrial man converts so much of nature and natural resources into waste and pollution that he is running out of space; he is losing the ecological resiliency that he formerly relied upon to absorb and reconvert the unwanted waste products of industrial, urbanized processes.

A few simple relationships, considered together, will indicate why deterioration of environmental quality poses such an ominous threat for the future of civilization. Consider these four realtionships:

1. Industrial activity with current technology is accompanied by output of waste products, pollution, and environmental change.
2. Industrial activity per human being increases as economic development proceeds.
3. Economic development is sought by underdeveloped nations, and encouraged and supported by the advanced nations.
4. Population in most nations on Earth is growing at unprecedented rates.

If these four relationships remain constant, the environmental pollution threat will be ominous, indeed. The planet Earth may well become uninhabitable; at best, the remaining life would be devoid of beauty and comfort. It is, therefore, important to examine the extent to which any of these relationships may be modified by society, so that it may continue to enjoy the fruits of economic development without suffocating and drowning man in his own wastes.

First, the relationship between human aspriations and industrial activity is not likely to change. In the foreseeable future, humans in both developed and underdeveloped nations will continue to strive for even more of the fruits of industrial output and affluence.

With respect to population trends, there may be some opportunity for more rational behavior. The Carl Dudley Duncans are no longer lonely voices. There is some evidence and some room for hope that, as income and educational levels rise and as technically and culturally acceptable means for family planning become available, the rate of population increase may be retarded. However, this is still a critical problem as optimum levels of population have already been exceeded in many nations. And it would be playing Russian roulette simply to assume that the total Earth population will decrease sometime soon.

Thus, we are left with only one alternative: The major hope for safeguarding habitability of Earth is to modify the current technological linkage between industrial activity and environmental pollution. The essential task of society, beyond that of controlling population, is to develop a pollution-free technology. Such is needed not only to maintain the viability of the already industrialized nations; it is needed to insure that the vast surge of industrial activity which is sought by developing nations will not corrupt the Earth further with waste and pollution.

It is not yet clear how technology can offer Earth civilization the means for correcting its own technological abuses of the environment. It may be necessary to plan, from the ground up, new combinations of advanced technologies in optimal relationships for recycling of pollutants, recovery of by-products, and prevention of environmental damage. Advanced planning of the location and structure of massive industrial complexes for minimum damage to the global environment will become necessary, requiring international cooperation for maximum benefits. Recognition of the international nature of watersheds, and the global nature of ocean currents and atmospheric phenomena, will indicate the necessity of extending areas of international agreement such as those now pertaining to world fisheries, peaceful development of polar regions, and the use of outer space.

Human society, in the future, will necessarily become more concerned with the qualitative, as opposed to the merely quantitative, aspects of economic development as it affects the environment and conditions of life. In this endeavor, the social scientists, using traditional and newly emerging tools of analysis, will play a significant role in identifying objectives and evaluating efficient methods for their achievement. In addition, protection and improvement of the human environment will require extensive modification of our legal, political, and other institutions. Knowledge and wisdom must come from all pertinent disciplines -- physical, biological, humanistic, and socio-economic -- and must be brought to bear systematically on the problem.

We need major reorientations of our past approaches to relationships between man and his environment. For example, social scientists have conventionally treated societies, including their economies, as open systems vis-a-vis the Earth. By an open system, I mean here the notion that the development of a society can be treated with the physical environment considered fixed and inexhaustible; that while societies receive inputs from the Earth, the atmosphere, and the waters, and give outputs into these reservoirs; societies can persist indefinitely so long as they have a capacity to draw upon the inputs and to get rid of the outputs. This is no longer a realistic approach.

The alternative to the open system, of course, is to view man and his environment as a single, integrated, closed system. As the economist Kenneth Boulding has noted, this concept makes of Earth a single spaceship, without unlimited reservoirs of anything, either for extraction or pollution. In this spaceship, which has external energy source in the form of the sun, man must find his place in a cyclical ecological system which is capable of continuous renewal of materials.

Another major reorientation, a corollary of the Spaceship Earth concept, relates to our singular emphasis upon Gross National Product and consumption as measures of economic success. In Spaceship Earth, the essential measure of the success of the economy is not production and consumption at all; rather, it is the nature, extent, and quality of the total capital stock, including the state of the human minds and bodies incorporated into the system.

Now, what resources does society have at hand to respond to this challenge? For our purposes, consider three: private producers and consumers, governments, and universities.

Neither private producers nor consumers, unfortunately, are likely to contribute as much directly to the solution of environmental quality problems as are the governments and universities. The private producer, operating within the established market system, is not likely to increase his costs of production voluntarily to avoid actual or potential pollution of the environment. The private consumer will attempt to preserve or create enclaves with relatively favorable environmental qualities. In the case of the producer, any inadvertent pollution he creates will tend to be treated as a costless externality unless some countervailing power is brought to bear, making it expedient to internalize the cost of avoiding or abating the pollution. In the case of the consumer, he will tend to exercise his individual freedom of choice to procure individual avoidance or reduction of pollution unless he becomes persuaded that his personal income expenditure on public abatement or reduction of pollution is to his personal advantage.

In simple terms, the market mechanism is not geared to handle transactions where general pollution abatement is desirable. To me, all this implies, much as I dislike it, further encroachment on our free enterprise system and individual liberties through governmental actions for the general welfare. Industry will be forced to internalize much of the cost of pollution control, just as it had to do with plant safety standards, minimum wages, and numerous other social costs. Individuals will lose some freedom of choice. For example, taxes have already made it very difficult to hold acreage for private recreational purposes; I can forsee the day when this will change from very difficult to impossible.

In looking at the potential of the Federal Government to implement an environmental quality program, we can identify some general obstacles which must somehow be overcome.

One serious obstacle, and one which I do not know how to overcome, is the general tendency for government in our deomcracy to react after a problem is acute rather than to anticipate it. We do not seem to be able to generate enthusiasm and resources until a major crisis of some sort is upon us; and this seems to be equally true of postal services, social services, and technological services. Personally, I believe that democracy is worth this price, and perhaps because I am already middle aged I'm willing to suffocate in foul air as a free man; but I have nagging doubts that this is really a necessary price to pay. Somehow there must be a way to make anticipatory action possible in our democracy, just as individuals are willing to defer immediate gratification for future ones when they save and invest their resources.

Another serious problem is that of governmental organization or, more appropriately in the case of environmental quality, government disorganization. During a tour of duty with the government in 1967 and 1968, I happened to represent the Department of Commerce on an interdepartmental group known as the Committee on Environmental Quality of the Federal Council for Science and Technology. This Committee supposedly kept some kind of an overview on all relevant activities in the federal government, but it had neither authority nor program responsibility. The plain fact of the matter is this: There is no integrated federal program in environmental quality at this time. Participating agencies number in the dozens, including various components of the Department of the Interior, the Department of Health, Education, and Welfare, the Atomic Energy Commission, the Department of Agriculture, the Department of Defense, and the Department of Commerce, to list only some.

The situation precludes the use of the Spaceship Earth concept as a working hypothesis. Each agency is necessarily limited by its own mission responsibilities, which tend to be founded upon limited sets of scientific disciplines and related technologies. The required multidisciplinary approach is strange to most government professionals who are accumstomed to working in discrete and well-defined areas.

Now, a single monolithic government program in the area of environmental quality is neither likely to emerge nor necessarily the best alternative. But the present fragmentation poses serious problems in implementing an integrated policy. Probably the most useful thing to do in this instance, believe it or not, would be to add to the bureaucracy. And that, indeed, was the recommendation of the task force on Resources and the environment one of many advisory panels set up by then President-elect Nixon shortly after the election last November. Specifically, the group chaired by Russell E. Train, now Under Secretary of the Interior, recommended (a) that the President appoint a Special Assistant for Environmental Affairs who would serve as a focal point for the government's scattered environmental concern, and (b) that the present inter-agency Council on Recreation and Natural Beauty should be broadened into a Council on the Environment with the Vice President continuing as chairman.

In response, President Nixon just last month established a new coordinating group, at the Cabinet level and under the Chairmanship of the Vice President, to deal with environmental quality. One must, of course, allow time for action or inaction before judgements are made. The people really doing the work will likely be the same ones sitting on the earlier Committee on Environmental Quality, for it surely will not be the Cabinet members themselves. But perhaps the group can be more effective with the stature that comes from speaking as a direct representative of a Cabinet member. This much seems clear to me: Some supradepartmental action component is needed if our federal government is to be effective in meeting the challenge of environmental quality.

Last, but not least, a word about the universities. They have a necessary and critical role to play if we are to achieve a viable environmental quality.

Education, research, and appropriate university services are indispensable to success.

Universities have their own problems, and they are not so dissimilar to those of government. Specialization and compartmentalization are rampant in academia. The tyranny of the traditional disciplines and the associated departmental structure seriously impede progress in an area such as environmental quality. To do their part, the universities must find ways and means to develop strong programs for the training of scientists to do research and analysis within the multidisciplinary framework of a total man-environment system. Reorientation away from the conventional wisdom of isolated disciplines is required of some faculty members and some of the students.

Universities must also educate policy level advisors and administrators for government positions in the field of environmental quality. This is related to, but distinct from, the program of research and analysis, since the qualities and skills required for these two types of activities are to some extent different. The commonality lies in the wide range of disciplinary inputs which is required.

Perhaps San Jose State College, as a flexible and developing institution, may break some new ground here. Certainly the creation of the Environmental Sciences Institute and the construction of Duncan Hall are significant and promising steps.

Man is in serious danger of losing control of both his numbers and his technology. If such control is lost, man's time remaining aboard this Spaceship Earth will run out rapidly. He will repeat the Biblical role of destroying an earthly paradise through his own actions. How long and under what conditions he can continue to enjoy his life on Earth depends on the extent to which he will be able to bring his knowledge and wisdom to bear upon restoring and protecting the quality of his environment.

DISCUSSION

QUESTION:

If you could wave a magic wand and solve one of the two problems you mentioned, which would solve first, better living standards for everyone or universal birth control?

BAUM:

I'm not sure that they're separate problems. I don't see how we can hope to increase the standard of living for the world at large without solving the population problem. I don't think the problem is whether we are going to manage to increase the standard of living, but rather whether we manage to survive with any kind of standard of living. . . I suppose the population problem would have to come first. I think that's a necessary condition.

QUESTION:

Earlier in the conference, Dr. Raven suggested that scientists ought to be more concerned with getting out and informing the public of the problems we're facing. Perhaps they should be even more concerned with communicating the results of their studies; this does run into the problems you mentioned of the present system in advancing the academic role. I would like to hear your comments on this problem; it does seem to be a problem.

BAUM:

There's no doubt that it is encumbent upon the scientific community to go out and tell the story more effectively, but there is also another side to that coin which I'll get to in a moment. The second part of your question seems to imply that scientists exist only in the academic community and, of course, that is not the case. It may well be that scientists in one community ought to focus the primary energies on one thing and scientists in other communities ought to be largely concerned with other problems. However, I think scientists have made great progress since the development of the atomic bomb in the 1940's in seeking to inject themselves into the public education and the policy-making process. Now, it's not easy to say that they've done as much as they might have, but they have done tremendously well in comparison with what they used to do.

I think there's a serious problem on the other side of the coin and that's that government bodies, by and large, have refused to face up to the fact that innumerable political decisions have a high component of science and technology built into them. The governmental bodies do not have and do not choose to put at their disposal, the kind of scientific and technological advice that should be available to those involved in the decision making processes. Now, the executive branch at the federal level has done pretty well. We have a scientific advisor to the President, we have a Presidential Science Advisory Committee, and so on. The executive branch has developed fairly reasonable resources. The legislative branch at the federal level has done far worse. Congress, although it has made some progress, has very little available to it in the way of sound and impartial scientific and technological advice in terms of policy-making. Now they are making progress on such issues as the ABM, for example, which is, for the most part, a technical question. They do call in people like Professor Teller, Professor Wiesner, and so on. This is more the exception than the rule.

When you consider the state and local governments where many of the decisions have major technological components, you find complete absence of any input into the scientific decision-making process on the part of scientists and engineers -- not that they should be making the decisions, but the state legislators, state chief executives, and the administrators of large municipality should have at their disposal competent, objective scientific and technological personnel to assist in decision-making. I think maybe there's a weakness in this aspect rather than in educating the public.

QUESTION:

I think what many of us want to know is how to influence populations of people like our own? How can we tell our colleges to stop littering our campuses and streets? How are we going to educate people? That's the problem?

BAUM:

Through mechanisms of this sort, through Rotary clubs, through newspaper stories . . . they're are the established mechanism. You just have to keep going out and harping away at the issue. I have no magic answer to this.

MAN AND THE WORLD ECOSYSTEM:

HOW MANY MORE PEOPLE DO WE WANT?

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SUMMARY

The explosive growth of the human population of the world, which may be attributed directly to the development of agriculture some 10,000 years ago, is now threatening the stability of the world ecosystem. Agricultural practices result in a considerable reduction in complexity with an accompanying loss in stability of the world's environments. In addition, chemicals introduced, for example, as pesticides and fertilizers are entering the ecosystems of the areas where agriculture is practised and severely damaging them. There are absolute limits to the size of the human population that the world can support and it is by no means certain that the carrying capacity of our planet has not already been exceeded by the 3.6 billion people who now inhabit it. Even if further increases are possible, they will cause a serious deterioration of the world environment and a loss of many of the amenities that we consider indispensable to human life.

POPULATION EXPLOSION

Ten thousand years ago when man discovered agriculture, there were fewer than ten million people in the world. By 1980, there will be more people than this in the San Francisco Bay Region alone. At the time of Christ, there were fewer people in the entire world than there are now in the United States. Today the world population amounts to some 3.6 billion people which, at the present rates, would become more than seven billion by the end of this century. More than 70 million people are added to the population of the world every year, despite the fact that about 40 million starve to death each year. Thus the population is not only huge, but it is doubling at a frightening rate. By the end of this century there may be some seven billion inhabitants sharing this planet with us and an ever-decreasing number of kinds of other organisms.

Population growth is sharply divided into two groups: the population growth of what are known as developed countries (or "have" nations which are relatively literate, well fed, and so forth) and the population growth of the "have not" countries (which are literate to a much more limited extent, relatively poorly fed, and with much dimmer prospects for the future). Developed countries like the United States and the U.S.S.R. have doubling rates of about 70 years, according to the 1969 figures prepared by the Population Reference Bureau; Japan has a doubling time of about 63 years, the United Kingdom of somewhat over 100 years, and some countries have even slower rates. On the other hand, India, which has approximately 537 million people at present, has a doubling time of 28 years, which means that after two decades of intensive work to try to curb population growth, India is still growing at a rate which infers that there would be a population of well over a billion by the end of the century. Pakistan, with 131 million people, has a doubling rate of 21 years, as does Mexico with 50 million people. The dubious honor of being the fastest growing country in the world goes to Costa Rica, with a population of some two million and a doubling rate of about 18 years.

At the present, there are about one billion people in the relatively slow-growing, developed countries and 2.6 billion in the rapidly growing, under-developed countries. In other words, the ratio between the "haves" and the have-nots" is changing rapidly. To illustrate this point still further, it may be mentioned that in 1950, there were about 200 million people in the United States and Canada and another 200 million in all of Latin America. By 1980, there will be approximately 250 million north of the Rio Grande and some 375 million to the south. Very soon, there will be twice as many people in Latin America as in the United States and Canada.

DOUBLING POPULATION

What does this doubling population mean? Simply stated, it means that in order to maintain current standards, a country must duplicate every building, every road, every schoolroom, every ounce of food --- everything that contributes to the standard of living of the people in that country. The United States, the wealthiest country in the world, would have a nearly impossible time in accomplishing this if the population were to double in 28 years. What chance has

India of providing for the more than one billion people that will live in India some 28 years from now *as well as* it now provides for its 537 million inhabitants? This observation alone points out the blatant hypocrisy of magazine articles that claim the "green revolution" is saving everyone in the world from famine, and soon there will be nothing whatever to worry about. We believe these stories becasue we want so badly to believe them, and unfortunately, not because they have a basis in fact.

Many experts believe that there will be widespread famine by 1975, and very few believe that it will not occur by the 1980's. For example, William and Paul Paddock, in their recent book *Famine -- 1975!* present cogent evidence that the total of 40 million people who starve to death annually in the world will soon be vastly increased. Approximately two-thirds of the present world population is inadequately nourished, and population growth has been forging ahead of increases in food supply since 1958. Despite this, the wealthy nations of the world continue to waste their resources on gigantic military establishments (which consumes about 60% of the entire budget in the United States) and on technological achievements of limited scope, such as sending rockets to the moon. One must wonder how long we will continue to be distracted from the central problems of the world by such spectacles.

LIMITED EARTH CAPACITY

There are absolute limits to the size of the world population set, for example, by the capacity of the earth to radiate heat back into space, which have nothing whatever to do with food. Not only is the problem of feeding the world's population insoluble in the face of a rapidly growing population --- a problem dealt with eloquently and at length by such authors as Borgstrom, Erlich, and the Paddocks --- but all of the other amenities of life on earth will rapidly vanish unless something is done about the problem. The ominous fact is that it is by no means certain that the world can support even its present 3.6 billion indefinitely, much less the enormous load that is anticipated. In the face of this, the pronouncements of Pope Paul VI on birth control are criminally irresponsible and dangerous as they mislead people into believing that this problem does not exist.

PROPOSED SOLUTIONS

Under the circumstances, it is not remarkable that Academician Andrei Sakharov of the USSR, Lord C. P. Snow of Britain, and American Nobel Laureate George Wald have recently made similar proposals for the solution of this overwhelming problem, all involving:

1. a complete rapporchement between the United States and the USSR,
2. a coordinated world-wide effort by developed and underdeveloped countries to limit population growth, and
3. a major world-wide drive to improve food production.

Sakharov's plan has been presented in an English version entitled "Progress, Coexistence, and Intellectual Freedom (W. W. Norton & Co., New York, 1968)." It imaginatively details ways in which world resources can be marshalled for the solution of these great problems. Presumably, special taxes will be necessary to provide an economic basis; but it is clear that if current levels of military spending are sharply curtailed, abundant finances will be available. Indeed, as Harrison Salisbury has pointed out in a commentary on Sakharov's essay, "The program proposed by Sakharov might well touch off the greatest economic boom in American (and world) history."

EFFECT ON AMERICAN SOCIETY

The United States is in no way isolated from the rest of the world. The population problem is our problem in the sense that we are a part of the world. But, it is also our problem in the sense that our own population is growing very rapidly. There were 130 million people in the United States in 1930, and there are well over 200 million today -- an addition of over 70 million people in less than 40 years. It is obvious that current population levels in the United States are high enough to provide country-wide pollution, destruction of the landscape, festering urban slums, racial unrest, and other desperately serious problems. Despite this, we continue to assume blithely that growth is good. We feel proud when our city, state, or country grows larger because growth "attracts industry," "makes jobs," and "keeps the economy running." Often unnoticed is the fact that growth also destroys most of what is considered desirable about a region; the San Francisco Bay Region is an excellent illustration of the conversion of a beautiful area into a tasteless, sprawling housing development. We are assaulted daily by offers of land, which is presumably rapidly appreciating in value, but we rarely pause to wonder what is happening to our state.

It is obvious that the size of the military establishment is one reason why the United States has been unable to resolve its domestic problems. What may not be so obvious is that an enormous fraction of our gross national product is used to duplicate existing facilities for the two million people that are added to our population each year. To maintain our standard of living at current levels in the United States, we must produce 1% more of everything -- schools, houses, drinkable water, food, toys, roads -- every year. What good does it do us to add two million people to our population annually? What might we not accomplish if the amount of money needed to duplicate existing facilities for them were devoted, instead, to solving the awesome problems that confront us now in our cities, and to increase our understanding of the factors involved in creating them?

We must begin to ask with Stewart Udall, whose 1976: Agenda for Tomorrow (Harcourt, Brace & World, Inc., 1968) is a thoughtful book that should be studied by all Americans, what good do we get as a country by adding all these extra people to our population? Why would it be good to have 300 million people in the United States some years from now -- why not keep the population stable at 200 million? We all know that when a population grows, the growth results in smog, pollution, urban problems, rivalries and tensions of all sorts, and indeed a loss of the most cherished democratic rights and privileges. Despite this, we continue to assume that adding to the population in some way contributes to our welfare.

I say that population growth is not a boon, but rather a drain on our resources as well as our spirit. I say it is high time that in the United States we gave serious consideration to how many people we want and precisely what this number would mean to the condition of the country that we inhabit. The alternative is simply to go on mindlessly increasing until we have 500 million, 600 million, a billion people in the United States and a nation in which no one would wish to live.

What we need -- both locally and on a global scale -- is the full realization that population growth is not good, does not benefit anyone except in the most limited sense, and if unchecked will ultimately lead to our destruction. We must stop being passive and accepting population growth, ugliness, and pollution as if they were inevitable. We control them; we can and must do something about them; and we owe this debt to ourselves and our children. It is high time that we, as a human race, stopped playing with such entertaining and self-perpetuating diversions as the Department of Defense and the exploration of space, and settled down to consider and solve the really important problems that face us. An exploding population is not something that just happens to us; it is something over which we have control. We may decide what kind of a San Francisco Bay Region, what kind of a California, a United States, or a world we wish to inhabit. But, to do so, we must realize that we do control the situation and dedicate ourselves to the task.

We live now in the best time in the entire history of the world. People have never known so much about their own nature, the nature of the world, or what man could be. At the same time, we live in the most dangerous time that man has ever known: dangerous because passivity could plunge us over the brink into an era when civilization, if not indeed human life itself, could well end. We must embark now on the creation of a veritable Utopia for all men because there is no real alternative. Any alternative that aims lower is doomed to failure and may well lead to extinction for us and for all other living things with which we share our planet.

RADIATION AND THE ENERGY BUDGET OF ORGANISMS

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SUMMARY

The single most ubiquitous property of the terrestrial environment is radiation. The influence of radiation on the temperature or energy content of an organism must be considered simultaneously in the context of other environmental factors affecting the energy budget of the organism. The other significant factors are air temperature, wind speed, and relative humidity. The spectral intensities and geometrical characteristics of various natural sources of radiation and the spectral properties of plants and animals are described.

The results of energy budget analysis for various plants and animals are given. It shows how the leaf temperatures and transpiration rates are accurately predicted for specific plants in given environments. The climate space within which an animal of given properties must live to survive is calculated. Specific examples are offered for a poikilotherm, the desert iguana, and for several homeotherms including a shrew, a cardinal, and a sheep.

The form of radiation with which we are concerned here is electromagnetic radiation and not strictly ionizing radiation. In the terrestrial environment of the biosphere, radiation is ubiquitous and into the aqueous environments a narrow spectrum of radiation may penetrate. Electromagnetic radiation is a transverse wave with oscillating electric and magnetic fields orthogonal to one another and orthogonal to the direction of propagation. Radiation is described by spectral quality or composition, by the degree of polarization, by the speed of propagation, and by the intensity. For practical purposes, we will consider two general classes of radiation: that which originates with high "color temperature" sources, such as the sun, incandescent lamps, and fluorescent bulbs; and that which originates with low "color temperature" sources, or thermal sources such as warm bodies and the surfaces of objects at ambient temperature. These two classes of radiation are referred to as short wave radiation and long wave radiation. Short wave radiation has a spectral composition made up of ultraviolet, visible, and near infrared wavelengths including monochromatic emissions or a continuum emission. Long wave radiation, or thermal radiation, is usually composed of a continuum emission in the far infrared beginning with a wavelength of about 4 microns and continuing to 30 microns with a peak intensity in the vicinity of 10 microns.

The various radiation components which are of significance to an organism within a terrestrial environment are illustrated in Figure 1 below. There

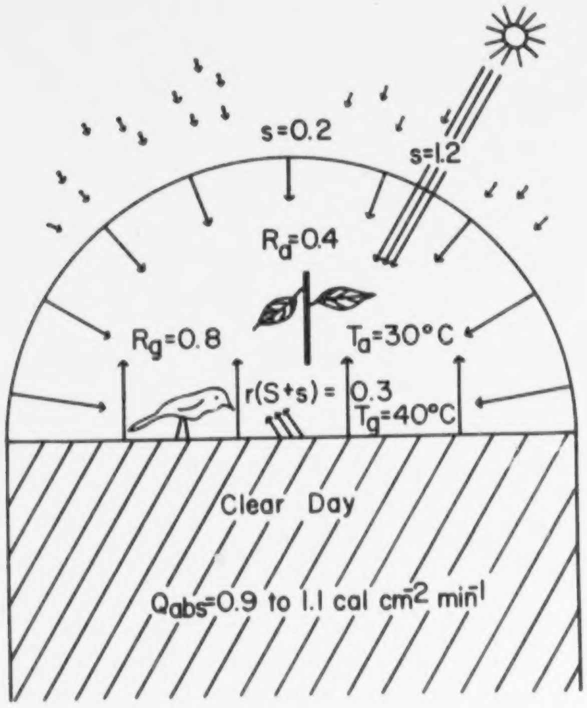

Figure 1. Radiative fluxes incident upon a plant or animal in a natural, clear day environment when air temperature is 30°C and amount of direct sunlight is S = 1.2 cal cm^{-2} min^{-1}. Under conditions shown the amount of radiation absorbed by the organism is between 0.9 and 1.1 cal cm^{-2} min^{-1}.

is direct sunlight, S, whose intensity at noon on a clear day may be about 1.2 cal cm^{-2} min^{-1}. The solar constant by comparison is 1.96 cal cm^{-2} min^{-1}. There is scattered skylight, s, whose intensity from the sky hemisphere gives a total irradiation of about 0.2 cal cm^{-2} min^{-1}. There is reflected sunlight and skylight, r (S + s), of intensity about 0.3 cal cm^{-2} min^{-1}. The atmospheric gases, water vapor, and carbon dioxide, emit thermal radiation, which from a warm, clear summer sky amounts to about 0.4 cal cm^{-2} min^{-1}. The ground surface, at a temperature of about 40°C, emits 0.8 cal cm^{-2} min^{-1} of thermal radiation.

The direct sunlight comes from nearly a point source in the sky and is primarily short wave radiation. The scattered skylight comes from a hemisphere and is primarily short wave, being relatively rich in ultraviolet. The reflected sunlight and skylight are of short wave radiation and are characterized as a combination of diffuse radiation from the lower hemisphere plus some specular reflection from bright areas. The longwave thermal radiation from the atmosphere and the ground comes from the upward and the downward hemispheres respectively.

Organisms are coupled to incident radiation by the spectral absorptance of their surface. If an organism were to reflect all incident radiation, i.e. act like a perfect mirror, its temperature or energy content is decoupled from the incident flux of radiation. If on the other hand, the organism is black and absorbs all of the incident radiation, then its energy content or temperature is strongly coupled to the incident flux of radiation. Most organisms are neither perfect reflectors nor perfect absorbers but absorb some fraction of the incident radiation in a manner which is very wavelength dependent. Figure 2 on the following page illustrates the spectral quality of the absorptance of a plant leaf (Mimulus cardinalis), a human hand, a white cat, a Pika, and a Steller's Jay. The most striking thing about these spectral curves are their differences. Each of these organisms located side by side having precisely the same radiation fluxes incident upon them will absorb the various parts of the spectrum differently and will absorb a very

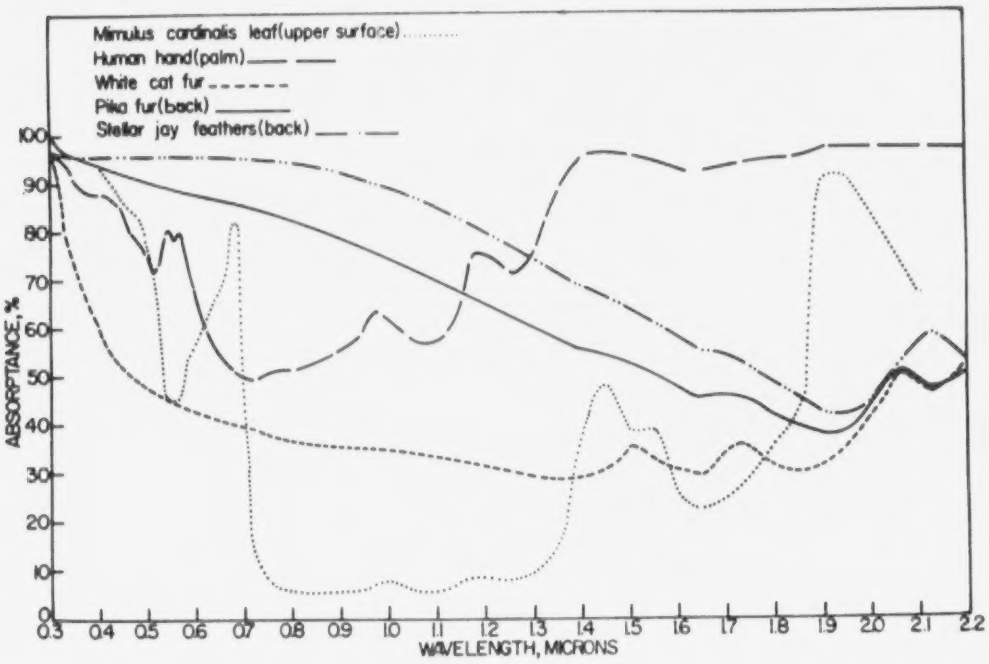

Figure 2. The spectral absorptance of a plant or animal as a function of the wavelength.

different amount of total radiation. The mean absorptance of the surface depends upon the spectral quality of the incident flux whose monochromatic intensity is R_λ . Hence, if a_λ is the spectral absorptance, then

$$\bar{a} = \frac{\int a_\lambda R_\lambda d_\lambda}{\int R_\lambda d_\lambda} \tag{1}$$

The actual amount of radiation absorbed by an organism located in a given environment depends not only upon the absorptance of its surface but upon its geometry, whether flat or round, etc., and upon its orientation with respect to the various sources of radiation. If the fluxes of radiation are designated R_i, the amount of organism surface area exposed to each source as A_i, and the mean absorptance of the surface to each source of radiation as $\bar{a}_i$, then for an organism whose total surface area is A the amount of radiation absorbed per unit area of surface per unit time is given by the following:

$$Q_{abs} = \frac{\Sigma\, a_i\, A_i\, R_i}{A} \qquad (2)$$

Radiation is one of the most complex features of any environment. It is most difficult of all the environmental properties to describe and by far the most difficult to evaluate. This very difficulty does not mean that we can or should avoid the description and evaluation of the radiation of the environment, nor of its interaction with any and all organisms. In Figure 1 it is estimated that the amount of radiation absorbed by the bird and by the plant leaves is between 0.9 and 1.1 cal cm^{-2} min^{-1}. At night the radiation flux becomes longwave only with no shortwave radiation. If the surface temperature of the ground was 15°C and the sky was clear, then $R_g = 0.56$ cal cm^{-2} min^{-1} and $R_a = 0.44$ cal cm^{-2} min^{-1}, and $Q_{abs} = 0.50$ cal cm^{-2} min^{-1}.

ENERGY EXCHANGE

Radiation absorbed by an organism manifests itself to the organism in terms of energy transfer. But the radiative exchange of energy is not the only process of energy flow. Energy is exchanged by convective heat exchange when an organism is immersed in a fluid, such as air or water. In addition energy is consumed in evaporative cooling if the organism sweats or transpires. An organism in direct contact with a colder or warmer substrate may exchange energy by conduction. An organism absorbs an amount of radiation Q_{abs} and then loses an amount $\varepsilon\sigma T^4$ by reradiation, an amount, $h_c\ (T - T_a)$ by convection, an amount LE by evaporation where L is the latent heat of vaporization (580 cal gm^{-1} at 30°C), and an amount by conduction C. The organism has a surface emissivity ε and a convection coefficient h_c.

σ is the Stefan-Boltzmann radiation constant, T_a is the air temperature, and T the surface temperature of the organism. In the case of a leaf the surface temperature is designated as T_l and in the case of an animal as T_r. Convective heat exchange may produce a heating rather than a cooling if $T_a > T$. Evaporative heat exchange will produce a warming of the organism surface if dew is being condensed on the surface rather than evaporated from the surface.

An organism must be in energy balance over any extended period of time. It cannot gain more energy than it loses nor visa versa. The analysis of the energy budget of plants and animals has been discussed in detail by Gates.[1] The mathematical results only are presented here. For a plant leaf whose width is D in a wind of speed V the energy budget is written

$$Q_{abs} = \epsilon\sigma T_l^4 + k\left(\frac{V}{D}\right)^{1/2} (T_l - T_a) + L\,\frac{{}_sd_l(T_l) - r\cdot h\cdot {}_sd_a(T_a)}{r_l + r_a} \qquad (3)$$

where ${}_sd_l\,(T_l)$ and ${}_sd_a\,(T_a)$ measured in gm cm^{-3} are the saturation vapor densities of water vapor at the leaf and air temperatures respectively. The diffusion resistance to the exchange of water vapor is r_l for the pathway within the boundary layer of air adhering to the leaf surface, each measured in sec cm^{-1}. The k in the convection term is a proportionality constant depending on the shape, orientation, and roughness of the leaf, the character of the wind -- laminar or turbulent, natural or forced convection.

The energy budget for the surface of an animal is analogous to that for a plant with the addition of metabolic heat and with the evaporative water loss divided into respiratory water loss, E_{ex}, and sweating, E_{sw}. Hence,

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[1] Gates, David M., 1968, "Energy Exchange Between Organisms and Environment," The Australian Journal of Science, Vol. 31, No. 2, 67-74.

$$Q_{abs} + M = \varepsilon\sigma T_r^4 + k \frac{V^{1/2}}{D^{2/3}} (T_r - T_a) + LE_{ex} + LE_{sw} + C \qquad (4)$$

where the surface temperature is T_r. In addition, the animal transfers heat across a layer of fat and in many cases across a layer of fur or feathers because of a temperature differential between the body temperature, T_b, and the surface temperature, T_r. This temperature difference is given by:

$$T_b - T_r = \frac{d_b}{k_b} (M - E_{ex}) + \frac{d_f}{k_f} (M - E_{ex} - E_{sw}) \qquad (5)$$

where d_b and d_f are the thickness of body fat and of fur or feathers respectively, and k_b and k_f are the conductivities of body fat and of fur or feathers respectively.

A homeotherm demands that its body temperature be reasonably constant and achieves this when exposed to a variety of climate conditions by varying M, E_{ex}, E_{sw}, d_b, and d_f in some appropriate manner. A poikilotherm on the other hand has relatively little control over these physiological and anatomical factors, but makes up for these handicaps by tolerating a large range of values to the body temperature. In either case, an animal adjusts its thermodynamics so that its body temperature responds to what amounts to a simultaneous solution to Equations 4 and 5. It is our desire to predict the climate within which an animal must live because of his intrinsic properties. Porter and Gates[2] have done this with the following animals: desert iguana, masked shrew, zebra finch, cardinal, ground squirrel, chipmunk, pig, and sheep.

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[2] Porter, Warren P. and David M. Gates, 1969, "Thermodynamic Equilibria of Animals With Environment," Ecology Monographs, in press.

It is clear from the brief outline of energy relations of plants or animals which is given above that the effect of radiation on a plant or animal cannot be considered outside of the context of energy flow by convection, evaporation, and conduction. In fact, it is the simultaneity of all these mechanisms of energy transfer which makes climate analysis and interpretation particularly difficult. Four parameters or independent variables describe climate, e.g. radiation, air temperature, wind, and humidity (including precipitation). If we ask about the influence of radiation on an organism we must say at what air temperature, wind speed, and humidity; otherwise the answer will have no meaning.

RADIATION AND PLANTS

In my discussion here I am not going to speak about the detailed photochemical reactions within plants. That is a very large and important subject. I shall speak only of the thermal or thermodynamic interactions as the result of radiation incident upon plants. The two direct responses of a plant to the energy available are in terms of leaf temperature and transpiration rate. There are other direct consequences such as photosynthesis, respiration, gas exchange, etc., but here we will confine ourselves to transpiration and temperature. Photosynthesis and respiration are subjects which we have discussed in considerable detail elsewhere.[3]

Figure 3 on the following page illustrates the dependence of transpiration rate and leaf temperature upon the quantity of radiation absorbed and the leaf dimension at a constant air temperature of 40°C, a relative humidity of 20%, a wind speed of 100 cm sec^{-1} (2.2 mph) and for a leaf whose internal diffusion resistance is 10 sec cm^{-1}. When radiation amounts absorbed are low the leaf temperature is below the air temperature and the transpiration rates are low. When radiation amounts absorbed are high leaf temperature is above the air temperature and transpiration rates tend to be high.

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[3] Gates, David M., 1968, "Toward Understanding Ecosystems," Advances in Ecological Research, Vol. 5, 1-35.

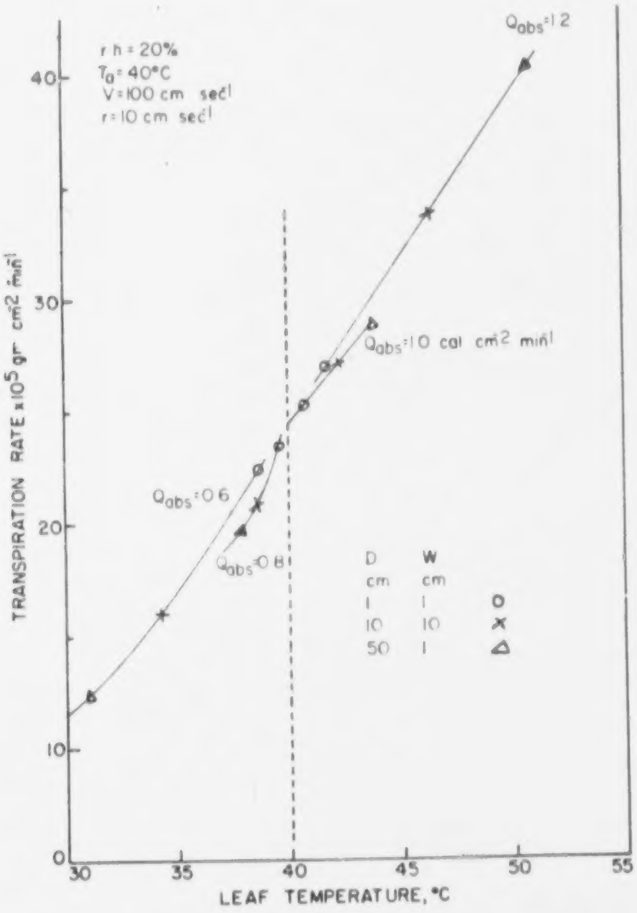
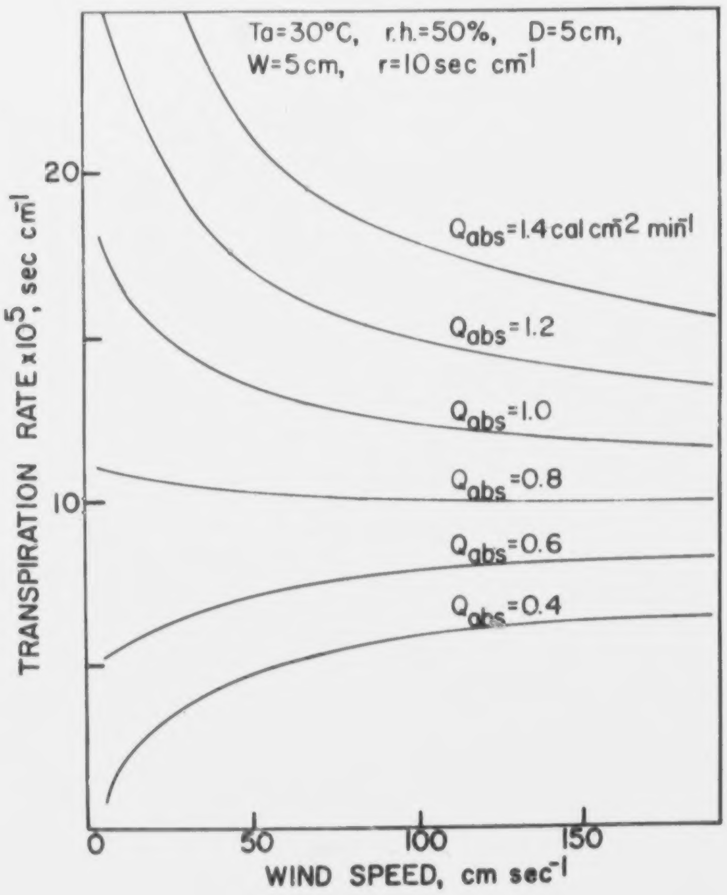


Figure 3. The transpiration rate and the leaf temperature of a leaf as a function of the amount of radiation absorbed and the leaf dimension for a wind **speed** of 100 cm sec^{-1} and an air temperature of 40°C for a leaf of internal diffusion resistance of 10 sec cm^{-1}.

It is also clear that the degree of influence of radiation depends on leaf size. This is the result of the influence on leaf cooling or heating caused by convection. A small leaf has strong energy exchange by convection and its temperature and the amount of radiation absorbed has less influence. When the leaf is large the convective heat transfer becomes small and the influence of radiation with respect to leaf temperature and transpiration becomes much more substantial.

Often one is asked about the effect of wind on the loss of water from a leaf. Does an increase of wind produce an increase or a decrease of water loss from a leaf? The answer depends upon the amount of radiation absorbed by a leaf as is clearly shown by Figure 4 below. At low amounts of radiation absorbed by a leaf an increase of wind will produce an increase in water loss, while at high amounts of radiation absorbed an increase of wind produces a decrease of water loss. For an intermediate amount of radiation absorbed



The transpiration rate as a function of the wind speed of a leaf of dimensions 5 x 5 cm whose internal diffusion resistance is 10 cm $\sec^{-1}$ in air of relative humidity 50% and temperature is 30°C.

wind may have no notable influence upon the rate of water loss. Throughout this disucssion the matter of high or low amounts of radiation absorbed is always relative to the level of blackbody radiation at approximately the air temperature plus 10°C. There is a complicated reason why this is true; in fact, the amount of radiation absorbed for which wind influence is small depends upon the diffusion resistance and rate of water loss from the leaf, but at a diffusion resistance of 10 sec cm^{-1} the equivalent blackbody temperature is approximately the air temperature plus 10°C.

Much more could be said concerning radiation and plants, but in order to have time to discuss radiation and animals, I terminate this discussion at this point.

RADIATION AND ANIMALS

It is our desire to present an analysis of the climate space in which an animal must live to survive from a thermodynamic or energy budget standpoint. Climate space designates the volume formed in four dimensions of all combinations of radiation, air temperature, wind, and humidity which produce the proper energy flow for a particular animal to be in thermodynamic equilibrium. The results of our work on this problem are summarized here only very briefly, but are reported in detail by Porter and Gates.[4]

In order to keep the presentation from becoming too complicated at first, we eliminate the humidity from consideration and present a two dimensional climate diagram with radiation and air temperature as the two axes and lines of constant wind speed within the diagram. Our first task is to describe strictly the physical environment and to present the relation between the amount of radiation available within a given environment which is compatible with a certain air temperature.

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[4] Porter and Gates, 1969, op. cit.

Figure 5, which is shown on the following page, describes the basis relation flux incident on an animal, assumed to be of cylindrical shape, and the air temperature of the habitat. The simplest situation to describe is that of an animal within a blackbody environment. Such would be an animal in a cave, room, burrow, or inside a dense forest with a closed canopy. Then the fluxes of radiation would be strictly thermal radiation from the walls or from the ground and plant leaves all considered to be approximately at the air temperature. For this condition the blackbody flux would be a precise result of the temperature of the air and surface. In the climate diagram the blackbody radiation is indicated as a dashed line.

The next simplest situation to be described is that of an exposed site at night where the animal is standing on the ground or sitting in the tree top and is receiving blackbody radiation from the ground surface and in addition receiving "grey body" radiation from the cold sky overhead. This relation as presented in the climate diagram is clearly to the left of the blackbody line and is shown as a solid line representing the minimum amount of radiation flux within the environment for a given air temperature.

When direct solar radiation, skylight, reflected light, and thermal radiation are incident on an object having the approximate shape of an animal, taken to be a cylinder, one can estimate the amount of radiation absorbed. In order to do so one must know the mean absorptance of the animal's surface. Furthermore there is a general relation between the amount of solar radiation incident at the surface and the air temperature for the following reason. When air temperature is warm it is usually late spring, summer, or early autumn and the sun is high in the sky at midday. When air temperatures are low it is usually late autumn, winter, or early spring and the sun is low in the sky at midday. Also in terms of any diurnal cycle the air temperatures tend to be higher when the irradiation by the sun is greatest.

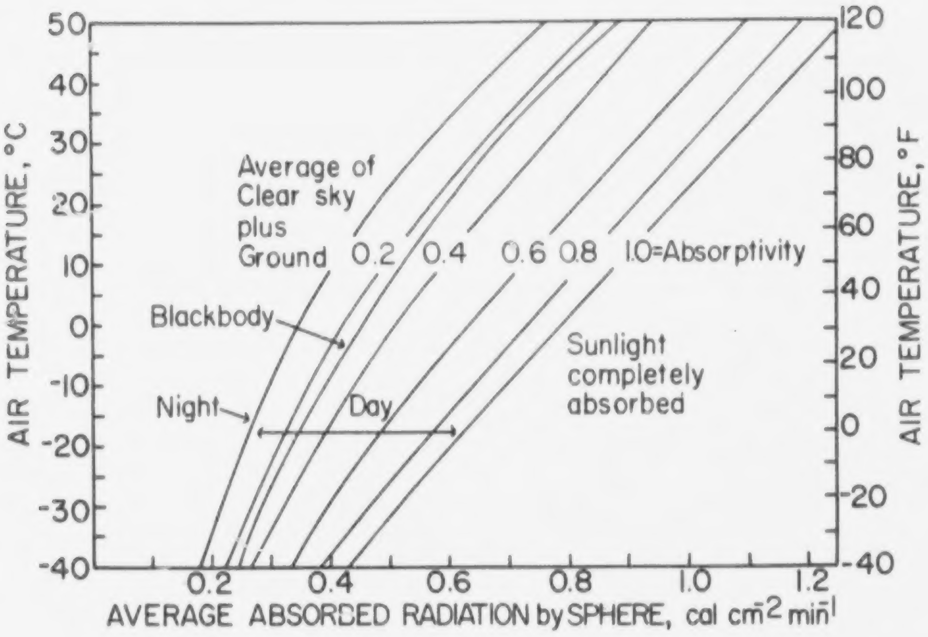

Figure 5. The physical relation between the amount of radiation available in an environment and the air temperature or the radiation available which is absorbed by a cylinder (representing an animal) whose absorbtivity to sunlight is a_s.

Hence one would expect the relation between the amount of radiation and the air temperature with sunshine to slope to the right in our climate diagram. If the absorptance of the surface is 1.0, the maximum amount of radiation (solar plus sky plus reflected light plus thermal radiation from ground and atmosphere) is given by the right hand line in Figure 5. There are exceptions to this line, such as the cold alpine tundra of the mid-latitudes at the summer solstice when the air temperature is low and the amount of radiation flux is high. However, there tend to be some compensating factors here which are interesting. Even though the amount of sunlight is very high for the alpine tundra the amount of thermal radiation from the clear, low density sky is very small and the amount of thermal radiation from the cold ground surface is small also. Although the position of the alpine tundra on the climate diagram may be to the right of the line shown in Figure 5, it is not very far to the right of the line.

Hence the climate diagram shown in Figure 5 presents the two-dimensional relationship between the air temperature and the amount of radiation incident upon, or absorbed by an animal as limited strictly by the physical properties of the environment. Now it is possible, by means of Equations 4 and 5 to delimit the diagram even further in terms of an animal's interaction with the environment. In other words, we can establish the environmental limits for an animal at a given air temperature, amount of radiation absorbed, and wind speed. In fact, wind speed only has significance when we introduce an animal into the analysis. The energy requirements or tolerances of a particular animal will limit the climate diagram in terms of its lower and upper extensions.

Figure 6 shows the climate diagram for a desert iguana and for a cardinal in the air at a wind speed of 100 cm sec^{-1} (2.2 mph). The cardinal, a homeotherm,

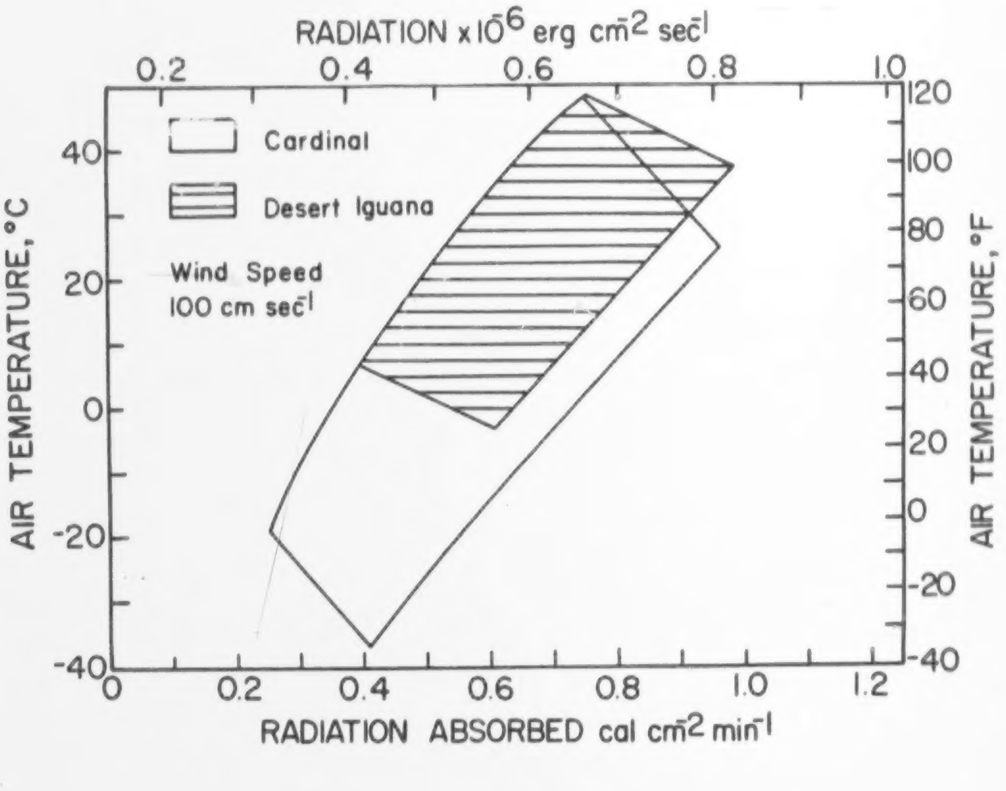

Figure 6. The climate space diagram for a cardinal and for the desert iguana showing the relation between the air temperature and the amount of radiation which can be tolerated for a wind speed of 100 cm sec^{-1}.

clearly has a much greater range of adaptibility than does the iguana, a poikilotherm. The cardinal, when the heat load becomes high, can dump a lot of respiratory water -- in fact, an amount almost equivalent to his metabolic rate under these conditions -- and as result is limited by the upper solid line shown in Figure 6. When in very cold, low radiation environment, the cardinal can increase his metabolic rate, reduce his water loss to a minimum, fluff out his feathers to improve his thermal insulation, and in various ways accommodate to a very cold condition. Throughout this entire range of conditions the cardinal's body temperature varies from a minimum of 38.5°C to a maximum of 42.5°C. The desert iguana on the other hand has relatively little control over metabolic rate and water loss rate, although it can vary these to some extent; it can allow its body temperature to get as low as 3°C and as high as 45°C.

The influence of radiation on the energy budget of animals is indicated clearly by Figure 6. A cardinal can remain in full sun with a wind speed of 100 cm sec^{-1} only with an air temperature less than 25°C. If the air temperature becomes greater than this the cardinal must move out of the sun into partial shade. If the air temperature reaches 42°C the cardinal in wind of 100 cm sec^{-1} must be in deep shade or in a "blackbody" radiation condition only. If the air temperature is 48°C the cardinal in wind of 100 cm sec^{-1} must expose itself to the clear cold sky acting as a radiation sink. The lizard can remain in full sunshine to substantially higher air temperatures than can the cardinal for two reasons: The first is that the iguana can have a higher body temperature than the cardinal. The second reason is that the iguana has an average absorptivity of 0.6 and the cardinal 0.8. At the low temperature end of the climate diagram the cardinal in full sunshine can endure an air temperature as low as -36°C with a wind speed of 100 cm sec^{-1} while the desert iguana cannot endure an air temperature less than about -3°C for the same conditions.

Most of the time any animal will locate itself well within its proper climate space and not approach too closely the extreme limits for survival. If the air temperature is 10°C under normal circumstances a cardinal may absorb 0.82 cal cm^2 min^{-1} of radiation and the lizard 0.73 cal $cm^{-2}min^{-1}$. However, even though the diagram does not indicate this, it is possible for the cardinal or for the desert iguana to absorb much more radiation than shown. In fact an extension of the solid line at the top of the diagram to the right would indicate the maximum amount of radiation a cardinal could absorb when in air at 10°C and at a wind speed of 100 cm sec^{-1} by finding the point of intersection of the line to the 10°C level. From the diagram a cardinal could absorb a maximum of 1.1 cal cm^{-2} min^{-1} in air at 10°C when there is a wind of 100 cm sec^{-1}. Whether this amount ever actually occurs in nature for these conditions is doubtful. For the desert iguana an extension of the dashed line at the top of the diagram would indicate that the maximum amount of radiation absorbed which could be tolerated in air at 10°C with a wind speed of 100 cm sec^{-1} would be 1.55 cal cm^{-2} min^{-1}. It is certain that this amount of average radiation absorbed by an iguana in air at 10°C simply would never occur in nature. The diagram, in effect, shows that at low air temperatures very large amounts of absorbed radiation could be tolerated by either animal, while at high air temperatures large amounts of radiation can never be tolerated.

Another generalization which can be made from the diagram is based upon the slope of the limiting lines at the upper and lower ends of the climate enclosure. If the animal is large then the limiting lines are very steep. This acutely affects the limiting amount of radiation absorbed which can be tolerated at a given air temperature and wind speed. A large animal cannot withstand large amounts of absorbed radiation when the air temperature is high because of poor convective cooling. This would be demonstrated in the diagram by a very steep line at the upper end. On the other hand a very small animal can withstand very substantial amounts of radiation when the air temperatures are high because of strong convective cooling. At the low temperature end of the diagram largeness of size permits very low air temperatures to be tolerated for rather modest amounts of absorbed radiation while very small animals are tightly coupled to the air temperature and very low air temperatures cannot be tolerated even with large amounts of radiation absorbed.

ACKNOWLEDGEMENTS

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DISCUSSION

QUESTION:
How do you make a difference between growing and languishing organisms with respect to irradiation?

GATES:
When a photosynthetic system is irradiated, it gives back quite a bit of the energy in the form of florescence and this florescence has quite long wave lengths. However, this only occurs when the cells are growing; it does not occur when the cells are just lying there. Thus, one can distinguish between growing and languishing organisms, if you will.

QUESTION:
Is there much concern about the increase in ultra-violet radiation with the increase in elevation in respect to sunburn?

GATES:
This is a tricky problem. As you increase in elevation, for instance, the ultra-violet increases, but not nearly as much as one would expect due to a combination of the scattering of ultra-violet by the sky and by the direct sun. On good, clear days at lower elevations, one can often get nearly as much ultra-violet as at a much higher elevation. Of course, at a lower elevation, one does not get as much ultra-violet as at higher elevations, but there is not so much of a change as one would expect; as you descend in elevation, you get more ultra-violet scattering out of the direct beam and it is thrown into the sky. In terms of ozone disruption, however, it would take quite a serious disruption before it would make a "hole" in the sky and get serious ultra-violet burning.

QUESTION:
Is your plan applicable to man?

GATES:
Well, it is certainly applicable to the estimation and evaluation of the human environment. The Army has done work on the human form and their data are now available. This sort of analysis is just now being done. The human is a bit more complicated than the model I've used on many other animals because of the enormous amount of surface and volume that is represented in the appendages. We're rather unique in this way; we have more appendage geometry than many other animals. But precisely the same kind of evaluation pertains to humans. There is good physiological data and we intend to work up some diagrams like this on humans, but we haven't had the time yet. For some reason, we've been more interested in cardinals, pigs, and desert iguanas.

QUESTION:
What differences in behavior are apparent between small and large animals with respect to thermal impact?

GATES:
A small reptile, for instance, can stay in the sun at a higher air temperature than a larger reptile. One must be very careful in interpreting the meaning intended here: The small one, because of convective cooling, maintains a steady state for an extended period of time. The difference between the two is quite substantial. However, if you are speaking of transient states of changing intensity, then a larger animal can endure longer in a situation of too much heat because it takes quite a while for its temperature to rise and adjust. Regarding a steady state, on the other hand, the small animal can stay in bright sunlight at much higher temperatures than the larger animal can withstand. This pertains particularly to a comparison of, say, reptiles and insects -- cold-blooded groups. It shows up strikingly in terms of insect behavior versus animal-reptile behavior. By knowing the climate niche, we can now predict what the metabolic rate must be to stay within a given environment. And knowing the metabolic rate, we can predict what the food supply must be. Once you find the particular components of food, you can begin to see how this animal combines climate and food in order to survive.

QUESTION:
Please comment on the CO_2 composition in the air?

GATES:
This is an extremely complicated question. The CO_2 is still increasing in the composition of air at a rate of 0.6 parts per million per year to perhaps 3.5 parts per million per year. It is apparently a steady increase. The photosynthesis of plants will rise with this increased supply of CO_2 which will increase productivity.

The whole matter of the radiative exchange in the atmosphere with CO_2 and water has been worked out quite thoroughly, particularly by some people at NASA in connection with satellites and infra-red observations through the atmosphere which have radiative fluxes. The interaction between the radiation components due to CO_2 and water is very complex. It has been a rough job determining what this means in terms of the temperature of the atmosphere. Yet, attempts have been made to accomplish this. I think one could say that the calculations indicate that the apparent warming trends are consistent with the increase in CO_2. But, we're now in a steep cooling trend and CO_2 is still increasing. Now, that's another story.

REMOTE SENSING OF WATER POLLUTION

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SUMMARY

Of the several fundamental criteria of water quality which is set forth in the report of the Committee on Water Quality Criteria of the Federal Water Pollution Control Administration, U.S. Department of the Interior, most would appear to be directly or indirectly detectable by the remote sensing technique of aerial photography utilizing black and white, color and infrared sensitive film.

In this paper, a theoretical approach to remote sensing of water pollution is outlined and the recommendation is offered that a research program should be initiated to correlate remote and contact sensory information. Such a program would doubtlessly enhance and speed the attainment of a national commitment to a program of improved pollution detection and control.

For countless centuries, man has looked outward from his earth toward the clouds, the sun, the moon, the planets, and the stars. He has seen the swift flash of meteorites, the majestic sweep of the comets, the mysterious lightening, the aurora, and the ghostly zodiacal light. Among these remote phenomena, he was touched only rarely by lightening and he could touch only the clouds. But, his endless quest for knowledge induced him to invent the transit, the telescope, the spectroscope, the camera, and the oscilloscope; and through measurement recording and research, he began to learn more and more about the systematic properties of his remote environment, until now he knows much about that which he has never touched.

Dissatisfied to be a remote observer of celestial phenomena, man has invented first the balloon, then the airplane, and finally the rocket to move ever closer to the remote objects of his curiosity. He is only slightly and temporarily satisfied when he can hold objects of his immediate environment in his hand, take them into his laboratory, and subject them to a detailed scrutiny which yields an almost infinite variety of information -- information which has made possible the Stone, Bronze, and Iron Ages, the Renaissance, the Industrial Revolution, the Atomic and the Space Ages.

In his seemingly endless flight toward the stars, man has also persistently looked back at earth. He has observed, measured, and photographed the earth from mountaintop, balloon, airplane, rocket, and finally from a spacecraft beyond the moon. He has perceived that photographs and measurements from a distance have a unique property of revealing widespread phenomena which may be entirely imperceptible to the untrained proximal observer. This is exemplified in photographs of the earth from space which clearly shows swirls of clouds in giant eddys that seemingly spin off the earth's poles, creating much of the earth's weather; or in the hues of the earth's seas and land masses -- hues determined by depth, temperature and moisture content as well as by vegetation, water vapor, ice, and snow.

But, remote sensing is not limited to observation of phenomena in the wavelengths of electromagnetic radiation perceived by the human eye. The emanations which we can create and detect with increasing power and sensitivity include light, heat, ultraviolet, radar and laser waves and beams. We use ultrasonics and sonar beams and can detect at a distance subtle changes in magnetic and gravitational fields. We can detect odor and particulates at great distances. Remote sensing is, thus, a descriptive term for those processes which involve the detection and measurement of phenomena at a distance. Applied to the human body, sight, sound, and smell are our remote senses. Taste and touch, on the other hand, are intimate or proximal senses. Remote sensing is accomplished through detection and measurement of the emanations of a body or its parts under the influence of internal or external excitation of natural or man-made origin.

It is not our purpose here to review the new, but extensive, literature of remote sensing. The general aspects of this field were ably reviewed recently in The National Geographic Magazine[1] and more technical treatments are those of Manello[2] and Stehling.[3] It is, rather, my purpose in this presentation to brifely explore some theoretical aspects of the application of remote sensing techniques to the detection and control of water pollution.

Although water pollution is continuously in the news today, it is, perhaps, less understood than remote sensing. One broad definition of the concept of pollution is "any condition which leads to adverse changes or modifications of any factor or condition in the natural environment." Applied to our earth's water resources, we now recognize that gaseous, liquid, and solid wastes contribute pollutants. Discharges from residential and commercial areas, industries, agricultural areas, forests, mines, and natural pastures all contribute to adverse changes in natural waters and, therefore, constitute pollution.

It is academic to separate man-made pollution and natural pollution, not because they are frequently interrelated, but because, in either case, they result in quality degradation. For example, excessive soil erosion may result from poor land management practices and/or from excessive rainfall. A practical view of pollution is that it is a condition which brings about any adverse change in the environment.

The ability (or, actually, the absolute need) to pollute is not a special property of man. All organisms pollute their environments in direct proportion to their metabolic activity; but man is unique in that he has learned to congregate in naturally impossible numbers -- conglomerations called cities.

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[1] Weaver, Kenneth F. January, 1969, "Remote Sensing -- New Eyes to See the World," National Geographic, 135, 1, 46.

[2] Manello, Gene G. December, 1968, "Aerospace Sensor Systems," Astronautics and Aeronautics, 6, 12, 26.

[3] Stehling, Kurt R. May, 1969, "Remote Sensing of the Ocean," Astronautics and Aeronautics, 7, 5, 62.

It is axiomatic that each area of land on the surface of the earth has limits of productivity and a limited capacity to absorb wastes. One definition of a city is, then, that concentration of population which exceeds the biological limits of the soil. Man is able to exceed the natural limits of population only through transportation and communication. A city must acquire food from areas hundreds of times larger than its built-up boundaries; and to avoid pollution, it should redistribute its wastes over an equal or larger area. Unfortunately, a city rarely has the foresight to move its liquid and solid wastes beyond the edge of town. Often the only export mechanism for such wastes is the air or a flowing stream. Solid wastes remain in the city and the city grows upward as well as outward, its new foundations resting upon the solid wastes of its earlier generations! The air, the soil, and the surface and ground waters, meanwhile, become eternally befouled with pollutants.

Although air and ground pollution are important, we are concerned here primarily with water pollution. As pointed out in a federal report on water quality criteria,[4] it is not sufficient to define water pollution as any adverse change in water quality. Rather, we require specific criteria of water quality and information regarding minimum levels of pollutants which permit the beneficial uses of water. For this reason, in Table 1 detailed quality criteria are presented as a function of use. Most of the items in Table 1 will be familiar to the reader; hence, only the most important ones will be discussed.

Epidemiological criteria such as the MPN for E. coli still must head the list of quality criteria for drinking water for the obvious reason that through application of these standards for potable water, we have attained our current freedom from enteric diseases.

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[4] Federal Water Pollution Control Administration, U.S. Department of the Interior, Report of Committee on Water Control Criteria, April, 1968.

Table 1. Quantitative Estimates of Water Quality Criteria for Water Resources

Use / Criteria	Drinking	Industrial	Agricultural	Swimming	Recreation	Fish & Wildlife	Shellfish
Epidemiological (E. coli MPN)	<1.0 org/100 ml <10% of 10 ml Portions Examined per Month	Depends on Industry	Low for Truck Crops	240-2400 org/100 ml 20% N.T.E. 1000	100-5000 per 100 ml*	None	<70/100 ml OK 70-700/100 ml Condem >700/100 ml Im-
Dissolved Oxygen D.O.	Adequate to Prevent Odors 5-10 mg/1	Nill for Boiler Feed Water	Must not Deplete D.O. in Soil	Adequate to Prevent Odors	Adequate to Prevent Odors	5 ppm or Greater, Depends on Species, pH, Temp.	Never Totally Absent 2-5 mg/1 min Depends on Temp.
pH	6.8-7.2 OK up to 8.0	6.8-7.2 Process Dependent	None	6.5-8.5* Some Alk. Lakes up to 10	6.5-8.5	6.5 to 8.5 Depends on Species, D.O.	6.5-8.5 Depends on Species
Biochemical Oxygen Demand (BOD)	<2-3 mg/1	Low, Depends on Industry	Low to Prevent Loss of D.O. Soil Sour or Clogging	Low Enough to Maintain D.O.	Low Enough to Maintain D.O.	Low Enough to Maintain 5 ppm D.O.	Low Enouth to Maintain D.O. Prevent Closeup
Algal Growth Potential (AGP)	5-10 mg/1	5-10 mg/1	50 mg/1	10-20 mg/1	10-20 mg/1	<20 mg/1	<20 mg/1
Grease & Floating Solids	None Allowable	Low	Low to Prevent Soil Clogging	None Allowed	Low, Wild Fowl Protection	Low, May Limit Oxygen Transfer	Low to Prevent Gill Clogging
Turbidity (Non-biological)	None Allowable	Usually None	Not too Important	Low to Permit Light Transmission	Low to Permit Light Transmission	Low to Prevent Silting or Gill Obstruction	Low to Prevent Silting or Gill Obstruction
Color	None Allowable	Depends on Process	Not too Important	Should Not Absorb Light	Not too Important	Not too Important	Not too Important
Temperature	10-20°C	10-20°C	Not Important	30-35°C	25-30°C	5-20°C	8-15°C
Toxic Materials	None Detrimental to Human Pb, NO_3^-, CN, F, Zn Heavy Metals	Depends on Process	Low Monovalent Cations Low Boron	None Detrimental to Humans	None Harmful to Equipment Acids, etc.	Cu = 0.001 ppm H_2S = 0.05 ppm CR = 0.05 $SO_4^{=}$5 Cl_2 = 0.3 Phenol 0.1	Very Sensitive to Org. Acids Cu, CR & High Bacterial or Algal Populations

*California Board of Public Health STDS for Water Contact Sports - Salt Water

1. No more than 10% of samples in one month in excess of 1000 MPN
2. No single sample in excess of 10,000 if confirmed by duplicate sample within 48 hrs.

The next most important criteria, particularly for wildlife, is dissolved oxygen. Unless they are hot or toxic, only waters with the lowest organic content will contain dissolved oxygen; therefore, the presence of dissolved oxygen is an excellent indicator of good water quality and concurrently an indication that the water is low in BOD and, hence, low in pollution and, therefore, suitable to support fish life.

Algal growth is a criteria which has been suggested to cover the entire complex of fertility in natural waters. Since our main concern with nutrients or fertility is that they may cause excessive plant or algal growth, a bioassay with indigenous algae grown under conditions such that no factor other than nutrient could limit growth, yields an estimate of the magnitude of algal growth which could occur should optimum conditions of all environmental factors coincide.

The presence of grease and floating solids in natural waters is obviously detrimental to quality and needs little elaboration. It is interesting to note, however, that pesticides such as DDT tend to accumulate in greasy deposits on natural waters.

Small suspended solids impart turbidity with little unsightliness. Natural waters are usually turbid because of the presence of silt. Both algae and bacteria in large numbers, finely divided precipitates such as iron sulfides or collodial sulfur suspensions also impart turbidity. Turbidity in any of these forms usually is undesirable for most beneficial uses of water. Color is an important criteria of biological activity and, if its occurrence is extremely intense, it is objectionable in drinking, recreational, and industrial process water.

Temperature is one of the most overlooked characteristics that can be closely related to the presence or absence of pollution. Much, but not all, thermal pollution results from direct discharge of hot waste liquids. Algae in water may convert light to heat with an efficiency in excess of 90 per cent of the incident sunlight, thus producing thermal stratification in nutrient-rich waters.

On the other hand, algae, like other black bodies, is a good absorber of radiant energy, causing water containing algae to cool down at night more quickly than water with no algae. Aquatic temperature profoundly affects the life cycle of most submerged organisms directly by influencing their life process rate and indirectly by affecting the solubility of dissolved oxygen and certain inorganic salts such as calcium carbonate and magnesium hydroxide. Temperature also affects the solubility of most gases as well as oxygen and their rate of diffusion into or out of the atmosphere. Finally, temperature profoundly affects lotic, benthal, and sessile decomposition and growth.

After examining these detailed quality criteria, it is worthwhile also to examine whether or not the physical manifestations of these criteria can be detected through use of some remote sensing technique. In this respect, we are, to a large extent, on uncertain ground because adequate correlative studies are lacking. Indeed, in most cases, owing to a lack of data, it is necessary to resort to theory and extrapolation. Nearly ten years ago, Fraga[*] suggested the possibility of applying remote sensing in detection of pollution. Putnam, Olson, and Bosch[5] have studied plankton and productivity in Lake Superior using aerial photography; and Strandberg[6] devoted a significant section in his excellent manual on aerial surveying to pollution detection techniques. In 1967, I was fortunate to have an opportunity to discuss the subject of remote sensing data and evaluation of water quality, not because of any expertise in remote sensing, but because of my work with water pollution.[7] Judging from the dearth of material published on the subject of remote sensing of pollution since that time, my recommendations met with less than overwhelming acceptance. It is my earnest hope that someone who hears me today will be moved to action with the full knowledge that the field is open to anyone willing to learn all there is to know of remote sensing and pollution. From my viewpoint -- which is rapidly becoming that of an elder, if not a statesman -- there is a great body of knowledge awaiting the inquiries of a diligent investigator. In this vein, rather than prepare a lengthy discussion of the subject, it is perhaps more worthwhile to systematically tabulate in very broad and incomplete terms, that which is partially or incompletely known, specifying where data is lacking. Such a tabulation is offered in Table 2, which shows certain criteria, a possible physical manifestation, and a method of detection which I believe has a good probability of success.

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[*] Fraga, Gilbert W., Personal Communication, January, 1961.

[5] Putnam, H., T. Olson, and H. Bosch, "Studies of Productivity and Plankton in Lake Superior," School of Public Health, University of Minnesota, June, 1961.

[6] Strandberg, Carl H. *Aerial Discovery Manual*, John Wiley and Sons, Inc., 1967, 249 pp.

[7] Oswald, J. "Remote Sensing Data and Evaluation of Water Quality," Proc. 3rd Annual Conf. on Remote Sensing of Air and Water Pollution, *15-1*, Cartwright Aerial Surveys, Inc., Sacramento, California, February, 1967.

In addition to those simple techniques of aerial detection set forth in Table 2, there is the technique of simultaneous photography on films sensitive to various wavelengths and simultaneous overlapping projection of these films to bring out subtle changes in color and, hence, emphasize certain characteristics of the observable phenomenon. This technique has been established by Colwell, et al. and was described briefly in the National Geographic article cited previously.[8]

Over and above qualitative information, quantitative information is needed to detect quality changes. Little quantitative information has been published relating detectable remote sensing characteristics and the quantitative responses resulting therefrom. I did, however, indicate a crude quantitative scale for dissolved oxygen in my previously-mentioned paper on the subject.[9]

Today we may be concerned with a lack of data, but, assuming that the necessary research were done, how could we best use the information? That is, given

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[8] Weaver, op. cit.

[9] Oswald, op. cit.

Table II

REMOTE SENSING OF WATER POLLUTION

Possible Emission Phenomena and Detection Technique for Water Quality Criteria

Criteria of Water Quality	Emission Phenomena	Detection Techniques
Bacteria	Indirect visible characteristics: turbidity, color or temperature	VC*, B/W* and IR* photography
Dissolved Oxygen	High DO absorbs light. Low DO scatters light (may be indirect).	Visible light, VC and B/W photography
pH	Possible emission change	VC photography
B.O.D.	Unknown possible increase in bacterial turbidity.	Unknown: VC possibly
Algal Growth	Black body adsorptive; red and IR fluorescence; fluorescence proportional to growth.	IR, B/W and VC light photography
Grease and Floating Solids	Particulates	VC and B/W photography
Turbidity	Light Scattering	VC and B/W photography
Color	Color emission	VC photography
Temperature	IR emission	IR photography Electronic sensing
Toxic Materials	Changes in typical plant or animal characteristics	VC, B/W and IR photography

*VC = Visible Color

*B/W = Black and White

*IR = Infrared

remote sensing techniques, how can these best be applied to solving or ameliorating the problem of pollution? To answer this question, consider the aerial photograph of Clear Lake, California which is shown in Figure 1. The scale of this photograph may be envisioned by knowing that the distance across the upper (northern) limb of the lake is 8 miles. In the narrow central portion of the lake, one can see what appears to be an emission which gives rise to some phenomenon, perhaps increased algal growth, which in turn, brings about the clearly visible variations in the black and white photographic characteristics of the great part of the lake. It is known that there is vigorous gas emission from the lake bed at the emission point, but the factors or quality characteristics which show up in this photograph are unknown.

Certainly an obvious answer regarding the value of remote sensing is that it may indicate, as no other method could, the strategic points where surface samples should be collected for analysis. It also points out the extreme variability which one may expect in surface samples. Perhaps most significantly, remote sensing can definitely establish the existence of pollution in terms which cannot be refuted and at levels which are subliminal for the proximal observer. Whether or not remote sensing can be employed effectively to detect detailed changes in water quality or other pollution related factors in the environment or to trigger certain pollution control measures or mechanisms is a subject which remains largely with the future.

DISCUSSION

QUESTION:

How do you make distinctions, because all of these categories seem to be very similar.

OSWALD:

I think that to make distinstions -- quantitative distinctions -- is going to take a substantial amount of research. I cannot tell you the answer to your question. The answer lies in the future.

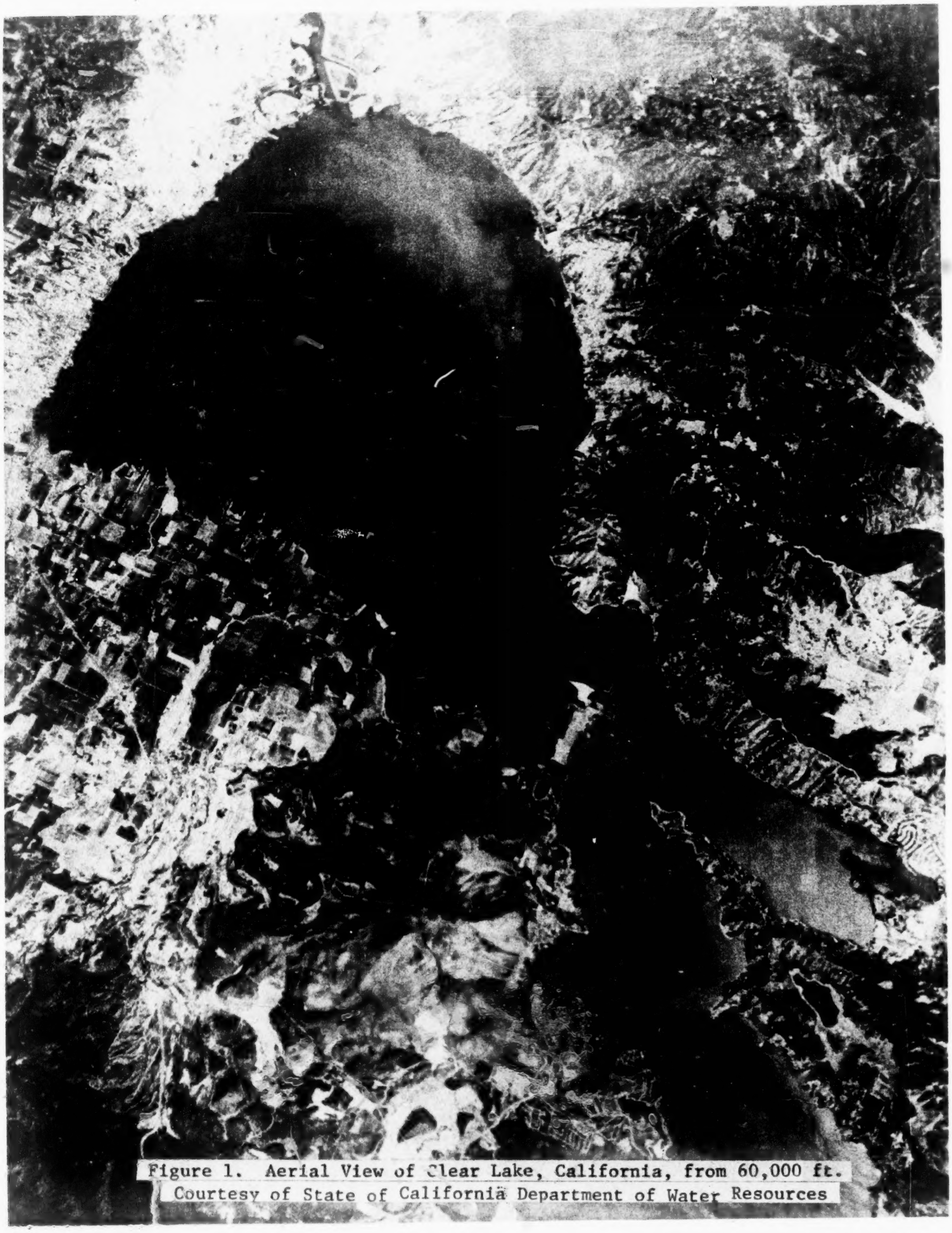

Figure 1. Aerial View of Clear Lake, California, from 60,000 ft.

Courtesy of State of California Department of Water Resources

INTERACTIONS OF CERTAIN ATMOSPHERIC POLLUTANTS WITH LUNG TISSUE

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Air and Industrial Hygiene Laboratory
Division of Laboratories
State of California Department of Public Health

SUMMARY

The trends for deaths from chronic respiratory diseases observed during the past two decades constitute a chronic disease epidemic. The upward trend is not merely peculiar to the United States. The lack of specific illnesses in humans from intermittent exposure, hopefully, should not be the sine qua non in establishing the potential hazard of our polluted atmosphere amidst the overwhelming experimental data.

The experimental observations which clearly demonstrate the increased susceptibility of the host to bacterial infection after the inhalation of ozone or nitrogen dioxide should be given a long, hard look.

For lack of evidence, one can only wonder whether the upward trend in our chronic disease picture is due to easy accessibility of our ubiquitous neighbors (microorganisms) on this planet to our lung parenchyma by virtue of a weakening of the defense mechanism by irritant gases in the atmosphere.

In a philosophic vein, the following questions come to mind: Are we rashly incurring too heavy a burden on the human body for the maintenance of a balance of nature of which we know very little, except that it is exceedingly complex and sensitive? To what extent, if any, is resistance to disease in man associated, as it often is with plants, with heritable factors which we may unwittingly be breeding out? Is anything that may be called a "conquest of nature" either practicable or desirable? Might it not be more prudent to try to live in harmony with our environment than to adopt an attitude of hostility toward it? And, in directing almost all our attention toward the mastery of our physical and biological environment, are we losing sight of the primary need for self-mastery? There is no end to such questions. Each suggests an entire range of further questions so that it would be a great task to answer any one of them completely. They are, however, more closely interrelated than they may appear to be as they are all concerned with the various aspects of a single phenomenon --- modern civilization. Those of us in the field of atmospheric pollution research have the tremendous task and responsibility of pursuing every promising avenue in order to provide the necessary guidelines in establishing atmospheric standards compatible with good health.

As early as 1661, polluted air has drawn complaints from city dwellers in London.[1] Since then, the urbanization of large communities throughout the world with their concomitant industrial development brought more and more indiscriminate dumping of waste materials in the air. Today the air we breathe is no longer considered to be an inexhaustible commodity, but, like water, it is now categorized as one of our precious resources. The objective of this paper is to examine the effects of air pollutants on mammalian lung tissue and the implicit consequences that these atmospheric agents may have on health.

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[1] Haagen-Smit, A. J. "The Control of Air Pollution," Scientific American, 210, 25 (1964).

Briefly, the major components of smog as found on the West Coast (notably in Los Angeles) are ozone, oxides of nitrogen and organic peroxides. This group of chemicals, known collectively as "photochemical smog," become extremely reactive oxidizing mixtures when catalyzed by sunlight irradiation.

The deleterious effects connected with photochemical air pollution are plant damage, eye irritation, abnormally high oxidant or ozone concentrations, and a decrease in visibility. The damage to plants and eye irritation are generally caused by reaction products form the oxidation of hydrocarbons and the oxides of nitrogen. In these oxidative reactions, ozone is formed and polymerization of organic compounds leads to the formation of nonvolatile oxidation and polymerized products which add to the pollutants from other sources such as smoke and sulfuric acid. The reaction which sets in motion the formation of these materials is a photochemical dissociation of nitrogen dioxide. Figure 1 illustrates the formation of air pollutants in a schematic form. The reaction is the fastest of all known primary photochemical processes[2] in polluted air and this is why nitrogen dioxide has been assigned a dominant role in initiating the processes leading to smog damage. Contributing reactions are the photochemical decomposition of aldehydes and formation of nascent oxygen. The reactive oxygen attacks organic material resulting in the formation of peroxyacetyl nitrate, peroxybenzoyl nitrate, in addition to ozone and other oxidative compounds.

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[2] Leighton, P. A. Photochemistry of Air Pollution, Academic Press, New York, 1961.

Figure 1. A Schematic Drawing Illustrating the Formation of Air Pollutants.

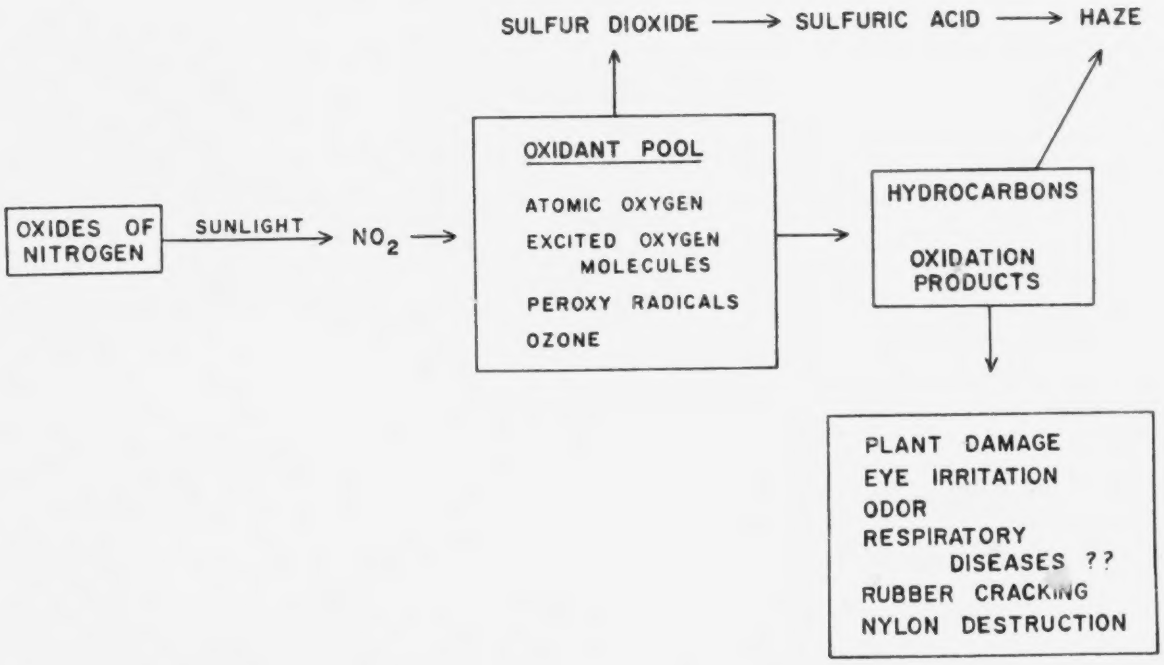
SULFUR DIOXIDE
SULFURIC ACID
HAZE
OXIDANT POOL
ATOMIC OXYGEN
EXCITED OXYGEN MOLECULES
PEROXY RADICALS
OZONE
OXIDES OF NITROGEN
SUNLIGHT
NO2
HYDROCARBONS
OXIDATION PRODUCTS
PLANT DAMAGE
EYE IRRITATION
ODOR
RESPIRATORY DISEASES ??
RUBBER CRACKING
NYLON DESTRUCTION

Table 1. Major Atmospheric Contaminants

Combustion	Aerosol	Specific Gases and Vapors
coal	dust, fume (smoke, fly ash)	NO_2, SO_2, CO, aldehydes, acids
fuel oil and gas	dust, fume (smoke)	SO_2, NO_2
gasoline (motor fuel)	fume (smoke)	NO_2, CO, organic acids, aldehydes, hydrocarbons*
rubbish	dust, fume (smoke, fly ash)	NO_2, CO, organic acids, aldehydes

*Mixtures containing types of hydrocarbons that are readily oxidized in the atmosphere.

The sources and composition of the major offenders which contaminate our atmosphere are illustrated in Table 1. It is interesting to note that all major sources of air pollutants produce NO_2.

In the history of man there have always been periods when one disease or group of related diseases presents a grave threat to the health of the individual and to the community. In the present period in which we live, we immediately think of heart disease as a leading killer and, increasingly, we are confronted by the growing number of individuals disabled by chronic respiratory diseases (chronic bronchitis-emphysema syndrome) and the high death rate from these and other chronic pulmonary conditions.

Zeidberg et al in a study conducted in Nashville, Tennessee, presented evidence that deaths from respiratory diseases increase in proportion to the degree of air pollution.[3] It was this observation and similar studies of the health effects of air pollution[4-9] which promoted greater awareness of this emerging problem in communities throughout the United States. Since reason for the observed deterioration of the atmosphere is the addition of trace substances, the question arises, why do we pollute the air in such an irresponsible manner?

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[3] Zeidberg, L. D. and Prindle, L. A. "Nashville Air Pollution Study: Pulmonary Anthracosis as an Index of Air Pollution," American Journal of Public Health, 53, 185 (1963).

[4] Admur, M. O., Melvin, Jr., W. W. and Drinker, P. "Effects of Inhalation of Sulfur Dioxide by Man," Lancet, 2, 758 (1953).

[5] Greenburg, L., Field, F., Reed, J. and Erhardt, C. "Air Pollution and Morbidity in New York City," Journal of the American Medical Association, 182, 161 (1962).

[6] Schoettlin, C. E. and Landau, E. "Air Pollution and Asthmatic Attacks in the Los Angeles Area," Public Health Report, 76, 545 (1961).

[7] Phelps, H. W., Sobel, G. W. and Fisher, N. E. "Air Pollution Asthma Among Military Personnel in Japan," J. Amer. Med. Ass., 175, 990 (1961).

[8] Dohan, F. C. "Air Pollutants and Incidence of Respiratory Disease," Archives for Environmental Health, 3, 387 (1961).

[9] Dean, G. "Lung Cancer Among White South Africans, British Medical Journal, 16, 1599 (1961).

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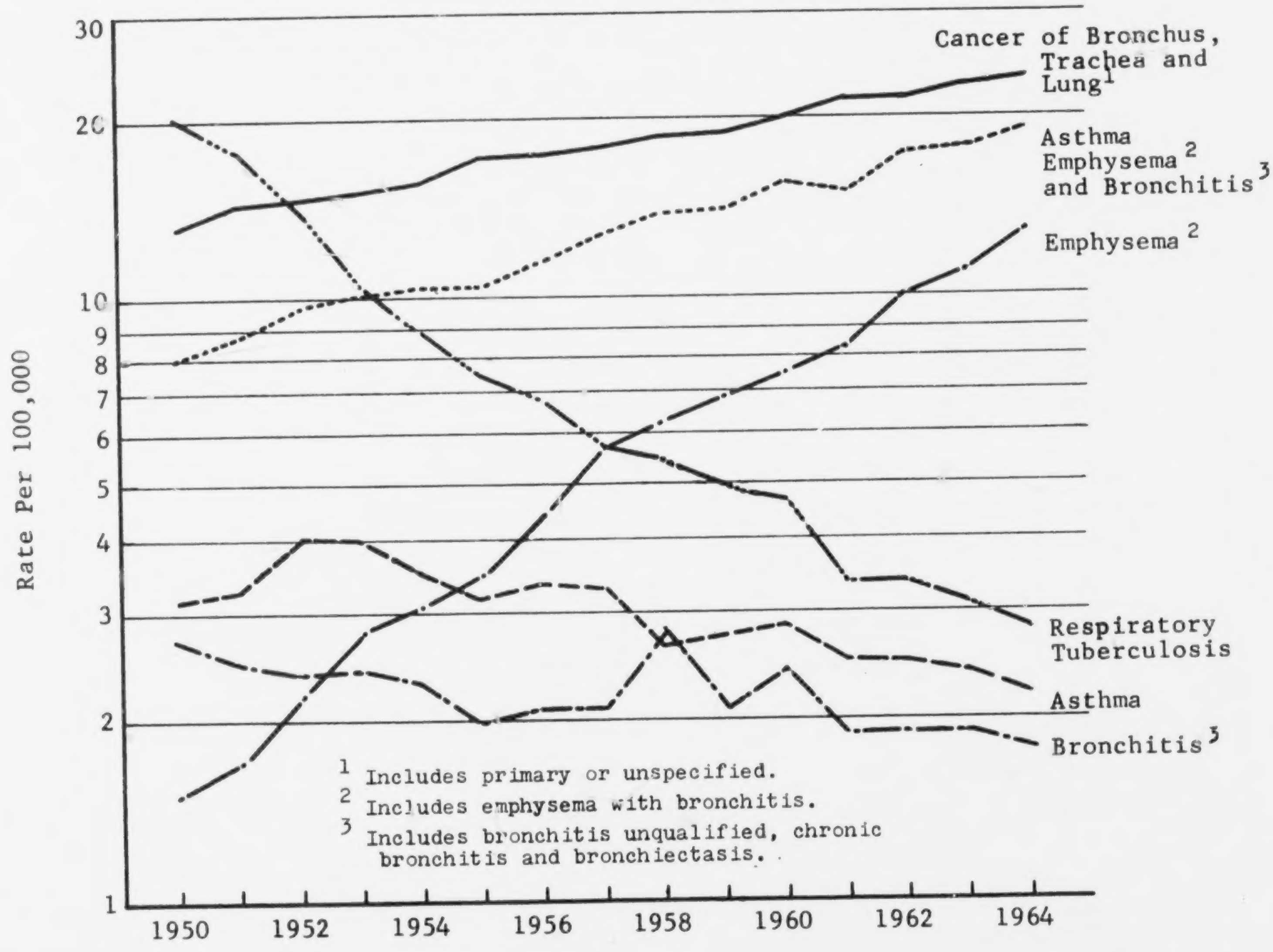
To most people, air and space are about synonymous; both seem to be available in unlimited amounts to please mankind. Our generation has discovered, to our great consternation, that nothing on earth is unlimited, or free, for that matter; and we have begun to worry about the limitation of our food supply, soil, water, and now our air. The air we breathe constitutes an important health resource and, as such, has acquired public interest by virtue of several ubiquitous factors. Namely, the trends for death (see Figure 2) from chronic respiratory diseases (principally chronic

Figure 2. Death Rates Due to Selected Respiratory Diseases in California 1950-1964



Source: State of California, Department of Public Health,
Death Records.

bronchitis, pulmonary emphysema, and bronchial asthma) constitute a chronic disease epidemic. Inasmuch as the actual mortality rates are not large when compared with such conditions as coronary heart disease, an increase of about 400% in chronic respiratory disease in a decade is alarming when compared with a 20% decrease in coronary heart disease during the same period. The upward trend is not just peculiar to the United States, but also occurs in England and Wales.[10] Furthermore, the increased mortality rate is not simply a manifestation of old age as it takes significant toll from males who are 40 to 60 years of age, as illustrated in Figure 3. The etiological factor is made more complex because chronic bronchitis, pulmonary emphysema, and bronchial asthma have similar symptoms (e.g., cough, excess sputum, and dyspnea) and produce the same type of functional abnormality (increased resistance to pulmonary airflow) as manifested by pulmonary function tests.

The establishment of a specific physiological change or biochemical pathway to identify incipient lung damage prior to functional aberrations of the lung has been somewhat difficult. The mechanisms of such changes remain unknown; consequently, there is no known parameter which reflects structural or chemical alterations of the lung as a result of environmental factors (air pollution) that are of inflammatory character. In a recent study by Becker, Schilling, and Verma,[11] on the health effects of the acute air pollution episode which occurred on the Eastern Seaboard of the United States during the Thanksgiving holiday in November of 1966, the following points were demonstrated:

1. As the air pollution levels increased, a greater response to symptoms of dyspnea, cough, sputum, eye irritation, and general discomfort was elicited from the study subjects. Conversely, as

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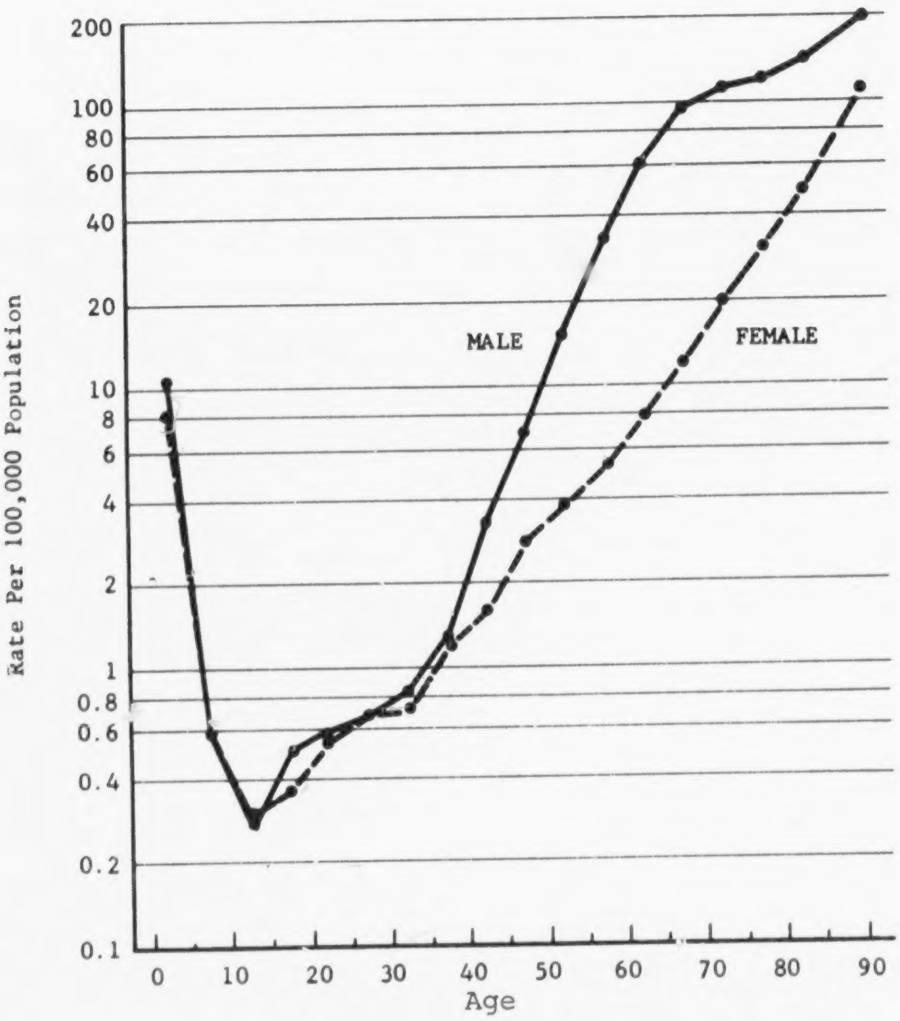
[10] Merrill, M. H. "Public Health Responsibilities and Program Possibilities in Chronic Respiratory Diseases," Am. J. Public Health, 53, 25 (1963).

[11] Becker, W. H., Schilling, F., and Verma, M. "Effect on Health of the 1966 Eastern Seaboard Air Pollution Episode," Arch. Env. Health, 16, 414 (1968).

Figure 3. Deaths From Chronic Respiratory Diseases in United States White Population, 1959



Source: State of California, Department of Public Health, Death Records.

the pollution levels lowered, the symptom responses decreased.

2. Subjects with a history of respiratory disease were affected more than the normal study participants.
3. Individuals with chronic obstructive pulmonary disease illustrated an increased affirmative response in all symptom categories.
4. Subjects smoking less than 10 or more than 20 cigarettes per day exhibited significantly greater symptom response than those subjects smoking 10-20 cigarettes daily. (This observation is different from what one might expect. The authors conjectured that subjects smoking less than 10 cigarettes per day have a low threshold of mucous membrane irritability and are more likely to respond clinically to elevated air pollution levels. As a consequence, they have limited themselves to 10 or less cigarettes a day.)

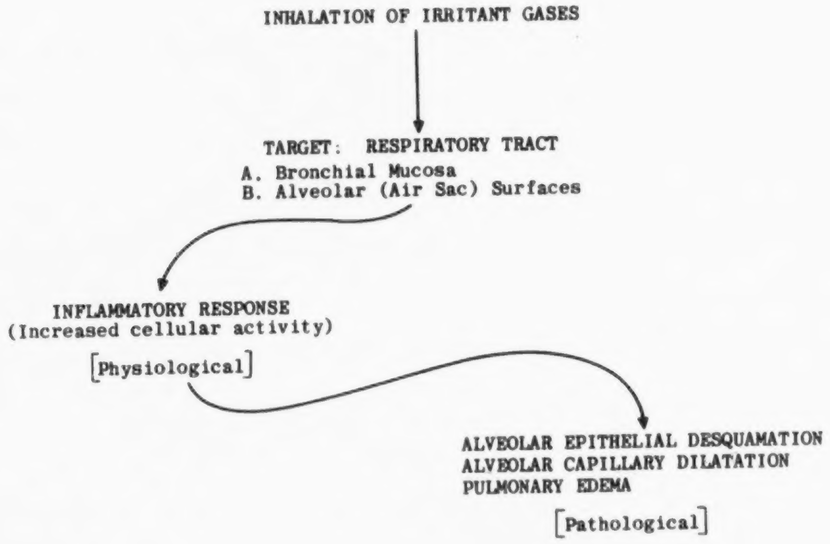
On the basis of these findings and other reported observations in the literature, it is difficult to perceive the actual magnitude of the relationship of air pollution to pulmonary diseases, as well as the factors involved in its etiology, onset, and course. One could ascribe the "iceberg phenomenon" to this pressing problem.

A hypothesis generally suggested for lung tissue damage incurred when certain air pollutants are inhaled is that the irritants (for example, photochemically induced oxidants) initiate the inflammatory process. If this is so, one could propose that the primary response results from the reaction of irritant gases with the protoplasm or the surface membranes of the cells which then undergo molecular changes and subsequent injury.

This paper is not intended to oversimplify the problem for the sake of schematization or sensationalize it for the sake of publicity. Furthermore, this review will cite only a fraction of the references in literature on the subject.

On this basis, therefore, the schema presented in Figure 4 is to orient the reader to the relationship of the inhalation of irritant gases to its effects

Figure 4. Schematic Drawing Illustrating Consequences of Irritant Gas Inhalation.


INHALATION OF IRRITANT GASES
TARGET: RESPIRATORY TRACT
A. Bronchial Mucosa
B. Alveolar (Air Sac) Surfaces
INFLAMMATORY RESPONSE
(Increased cellular activity)
[Physiological]
ALVEOLAR EPITHELIAL DESQUAMATION
ALVEOLAR CAPILLARY DILATATION
PULMONARY EDEMA
[Pathological]

on lung tissue -- to paraphrase, the interaction of living systems with their environment. The sequence of events culminating in a pathologic condition, as shown in Figure 4, is nonspecific for irritant gases of low solubility; however, this condition appears to be most characteristic of NO_2. Nitrogen dioxide is a biologically active compound in addition to being stable. The hazardous nature of this gas in man has been demonstrated in many manufacturing operations in the form of industrial accidents. There is, in addition, a constellation of information in the scientific literature regarding the effects of NO_2 exposure on many species of animals. The results of these experiments, inasmuch as they cannot be extrapolated to man, must be seriously considered in the light of the evidence being accumulated contra, and the more precise tools available to investigators today.

Specific biologically adverse effects of photochemical air pollution observed in animals and man follows. It has been reported that cadmium fumes inhaled accidentally by men during welding produce similar proliferative changes as occur when experimental silicosis is induced.[12] Mention should be made here that appreciable levels of ozone by arc welding devices have been found. Thus, one is immediately confronted with the complex nature of the problem. That is, are the cadmium fumes (a mixture), or the ozone, or both responsible for the observed pulmonary changes? Stokinger's review of ozone toxicology[13] clearly elucidates the injurious potential of ozone in man, animals, and microorganisms. It should be pointed out that total oxidant readings have been used as an index of peak ozone hazard in air pollution. According to Cherniack and Bryan[14] the contribution of any single compound to the total oxidant value varies with its concentration and its oxidizing capacity. Ozone contributes 90% or more of the value when it is the major oxidant present during periods of heavy pollution.

The *in vitro* studies of Pace *et al*[15] indicate that ozone, even in relatively low concentrations (4 ppm) appears to have an inhibitory effect on cell proliferation depending upon the length of exposure. These investigators suggest that O_3 may alter the cell membrane, as indicated by the appearance of blebs in many of the cells that had been exposed. This observation may well confirm the edemagenic* effect of O_3 observed by others in lung tissue. Another observation worthy of mention is the study of Miller, Erlich[16] and Purvis[17] who demonstrated in laboratory animals that the inhalation of O_3 lowered the resistance of the host to bacterial infectivity. The effect was demonstrated by enhanced mortality after the challenge with airborne microorganisms, and by reduced clearance rates of the infectious agent from the lungs. The concentration of O_3 employed in these studies ranged from 0.8 ppm to 4.4 ppm.

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[12] Gross, P. "Mechanisms of Some Structural Alterations of the Lung," *Arch. Env. Health*, *14*, 883 (1967).

[13] Stokinger, H. E. "Ozone Toxicology," *Arch. Env. Health*, *10*, 719 (1965).

[14] Cherniack, I. and Bryan, R. J. "Comparison of Various Types of Ozone and Oxidant Detectors Which Are Used for Atmospheric Samplings," *J. Air Poll. Control Association*, *115*, 351 (1965).

[15] Pace, D. M., Landolt, P. A., and Aftonomos, B. T. "Effects of Ozone on Cell *in vitro*," *Arch. Env. Health*, *18*, 165 (1969).

*Pulmonary edema, in this context, is considered to be a state in which there is an excess storage of water and solutes in the lung parenchyma and/or alveoli. The assumption is made here that pulmonary edema production is a phenomenon describable in terms of movements of water produced by abnormal hydrostatic pressure and concentration gradients across normally or abnormally permeable membranes.

The propensity of this gas to enhance the development of bacterial infection of the lung was also demonstrated by other investigators at levels as low as 0.08 ppm for a three-hour exposure to O_3.[18] The study by Young et al which showed the individual human susceptibility to ozone at a concentration of 0.6 ppm for two hours[19] would certainly tend to confirm the concept that certain irritant gases may cause increased sensitivity to histamine in the lung of animals.

Nitrogen dioxide, also an edemagenic agent when inhaled, produces similar sequential pathologic events as ozone. It is interesting to note that rats[20] and mice[21] exposed to a relatively low concentration of 0.5 ppm of

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[16] Miller, S. and Erlich, R. "Susceptibility to Respiratory Infections of Animals Exposed to Ozone," "Susceptibility of K. Pnuemoniae," Journal of Infectious Diseases, 103, 145 (1958).

[17] Purvis, M. R., Miller, S. and Erlich, R. "Effect of Atmospheric Pollutants on Susceptibility to Respiratory Infection. 1. Effect of Ozone," Journal of Infectious Diseases, 109, 238 (1961).

[18] Gardner, D. E., Holzman, R. S., Coffin, D. L. and Wolock, F. J. "Influence of Ozone on Pulmonary Cells," Arch. Env. Health, 16, 633 (1968).

[19] Young, W. A., Shaw, D. and Bates, D. "Effect of Low Concentrations of Ozone on Pulmonary Function in Man," J. Appl. Physiol., 19, 765 (1964).

[20] Thomas, H.V., Mueller, P. K. and Wright R. "Response of Rat Lung Mast Cells to Nitrogen Dioxide Inhalation," J. Air Poll. Control Ass., 17, 33 (1967).

[21] Blair, W. H., Henry, M. C., Erlich, R. "Chronic Toxicity of NO_2. II Effect on Histopathology of Lung Tissue," Arch. Env. Health, 18, 186 (1969).

NO_2, a common occurrence in the Los Angeles area, show alterations in lung morphology. Furthermore, and exceedingly inportant in the opinion of this author, such a low level of NO_2 has been shown to enhance the pathogenic effects of challenge with *K. pneumoniae* in mice.[21] Blair *et al* concluded in their experimental studies that the overall lesions in mice after NO_2 inhalation (0.5ppm after 3 to 12 months) appeared to be consistent with the microscopic development of early focal emphysema. This observation is not inconsistent with the findings of Freeman and Haydon, who have reported that chronic exposure to NO_2 does produce an emphysematous-like lesion in the lungs of rats.[22]

Biochemical observations in animals by Buell *et al*[23] have demonstrated the denaturation of protein in the lungs of rabbits exposed to NO_2. Similarly, lipoperoxidative changes *in vivo*[24] as well as alterations of phospholipids in rat lung tissue have been observed. The fact that these observations were made after exposure to low concentrations (0.25 to 5 ppm) under acute conditions would appear to add greater concern about the toxicological effect of this gas on man.

Structural observations have been reported in animals after NO_2 inhalation. Some of these changes include crystalloid inclusions,[25] vacuolated lamellar bodies, and the appearance of multivesicular bodies. A peculiar type of lung injury was observed in mice in the Los Angeles area recently and was associated with pollutants in the atmosphere. This work of Bils[26] revealed structural changes in mice exposed to two to three hours of heavy air pollution daily. Gross examination of the lungs of the exposed animals in the above acute* studies revealed no consistent differences when compared with the controls; however, changes in the fine structure were noted by electron microscopy.

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[21] *Ibid.*

[22] Freeman, G. and Haydon, G. B. "Emphysema After Low-Level Exposure to NO_2," *Arch. Env. Health*, *8*, 125, (1964).

[23] Buell, G. C., Tokiwa, Y., and Mueller, P. K. "Lung Collagen and Elastin Denaturation *in vivo* Following Inhalation of Nitrogen Dioxide." Presented to the 59th Annual Air Pollution Control Association Meeting in San Francisco, California, in June, 1966.

[24] Thomas, H.V., Mueller, P. K., and Lyman, R. L. "Lipoperoxidation of Lung Lipids in Rats Exposed to Nitrogen Dioxide," *Science*, *159*, 532, 1968.

[25] Freeman, G., Stephens, R. J., Crane, S. C. and Furiosi, N. J., "Lesion of the Lung in Rats Continuously Exposed to Two Parts Per Million of Nitrogen Dioxide," *Arch. Env. Health*, *17*, 181, 1968.

Although no attempt is being made here to extrapolate the above data from animals to man, the evidence is rather convincing that the ambient atmosphere may be a scourge created by our technological achievement. If we are to talk about good health and the environment for good health, it may well be that we must turn around and confront some realities --- speak about them frankly and bring to bear upon them some of our best professional judgements, resources, and efforts.

The health effects of air pollution have not only been demonstrated in the United States, but in other parts of the world as well. Worthy of mention is the observation in Yokkaichi, located in the central part of Japan along the Pacific Coast[27] where there were only a few cases of respiratory diseases until several years ago. With the subsequent installation of electric power stations, oil refineries, and petrochemical plants, growing numbers of bronchial asthma, chronic bronchitis and airway obstruction among inhabitants have been observed, especially among those over 40.

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[26] Bils, R. F. "Ultrastructural Effects of Air Pollution on Lung Cells," J. Air Poll. Control Ass., 18, 313 (1968).

[27] Yoshida, K., Oshima, H., and Imai, M. "Air Pollution and Asthma in Yokkaichi," Arch. Env. Health, 13, 763 (1966).

*A typical acute exposure is one in which the target organ is exposed to a relatively high dose, followed by early and severe biological consequences. Chronic exposure is one in which relatively low doses are given continuously as an extended series of irregular exposures over a prolonged period.

Asthmatic attacks evident in individuals in this area disappear immediately as soon as the patient has been moved to a relatively unpolluted area. Ury's statistical treatment showing a significant association between Los Angeles motor vehicular accident frequencies with the levels of oxidant in the atmosphere is worthy of note if for no other reason than to illustrate the clever application of nonparametric techniques.[28]

Finally, a recent report by Fredrick Li of the National Cancer Institute revealed cancer mortality among chemists to be significantly higher as opposed to non-chemists.[29] Li states as an explanation that his findings may be a consequence of exposure to chemical reagents.

DISCUSSION

QUESTION:

Is the odor that we smell during heavy smog caused by NO_2?

THOMAS:

No. The odor that we detect is that of ozone. You will recall that I showed a slide designating an oxidant pool. This pool consists of ozone, reactive oxygen, peroxy radicals, and atomic oxygen among others. When the oxidant level is measured we are actually obtaining a measurement of what is largely ozone. The schematic illustration on the slide may have been an over simplification of the actual process.

QUESTION:

Is ozone a by-product?

THOMAS:

Yes, it is a by-product.

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[28] Ury, H. "Photochemical Air Pollution and Automobile Accidents in Los Angeles," Arch. Env. Health, 17, 334 (1968).

[29] Editorial by Robert Bernhard, "Cancer Danger for Chemists," Scientific Research, April 28, 1969.

QUESTION:

On your antioxidant slide you got a much better score with BHT alone than you did with BHT and Vitamin E. Could this be antagonistic effects?

THOMAS:

I do not know. I cannot answer that question. However, I would like to make a clarification: BHT, like BHA and DPPD, is a synthetic antioxidant made expressly for one purpose -- that is, as an antioxidant. Now, Vitamin E is not only a natural antioxidant, but it also plays an important role in reproduction, maintaining the integrity of cellular structures, etc. Therefore, I would suspect that one of the functions of Vitamin E as an antioxidant is not as potential, let us say, as a synthetic antioxidant such as BHT.

QUESTION:

What are the highest volumes of NO_2 found during smog?

THOMAS:

Do you mean highest values? Well, the highest value detected about a year or so ago was approximately 1.4 ppm for a very short duration. However, the highest peaks which occur in heavy smog attacks with some frequency is about 0.5 ppm. At one time this value was considered as very high. These values I am quoting are from the Los Angeles area. High peaks have reached 0.89 ppm.

PESTICIDE KINETICS IN ECOSYSTEMS DISTURBED BY MAN

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Davis, California 95616

SUMMARY:

The presence of novel chemicals in natural systems is a by-product of a technological society. Accelerated use of pesticides in the years following World War II has resulted in a worldwide deposition of their residues. To the ecologist, normal pesticide usage poses two major difficulties. First, pesticides are biologically active and regularly strike at non-target organisms as well as their intended targets. Biocide is, therefore, a better term for these toxic chemicals. Secondly, many biocides persist in the environment and the biological consequences of their presence cannot easily be forecast. The second category of effects is more serious. Not only are the effects largely unpredictable, but they act as temporal, biological, and spatial distances whose routes of transfer and action are very poorly known. Fluid (air and water) transport systems are largely responsible for widespread dispersal from sites of application. Following dispersal, differential magnification of residues occurs by environmental concentrators such as molluscs and along food-chains in trophic sequences. The death of individuals, reproductive inhibition, and threatened extinction of species are demonstrable results of the presence of surviving residues of these new chemicals in the earth's ecosystems.

The presence of novel chemicals in natural systems is a consequence of technological man. The appearance of such synthetic chemicals and the effects that they produce have no precedent in organic evolution. Most pesticides as we know them today have no natural counterparts. Less than 25 years ago most did not exist. Accelerated use of organic pesticides followed during the years after World War II. The residues of many pesticidal compounds, most notably DDT, are distributed world-wide. One DDT metabolite -- DDE -- has been called the commonest and most widely distributed synthetic chemical on the globe. DDE can now be found in biological tissues from the open ocean to the polar ice caps, in airborne dusts over cities, and in plants, animals and waters in remote forests and mountains.

Pesticides are biologically active chemicals. They must be highly so to achieve the intended purpose of animal control. The spectrum of activity is, however, sufficiently broad in most instances as to justify the more applicable word, biocide. In sum, therefore, pesticides are widely distributed by natural means; but, in contrast to natural materials such as dusts, retain a good part of their biocidal activity.

To the ecologist, normal pesticide use poses two major difficulties. First, pesticides are biologically active and regularly strike at non-target organisms as well as their intended targets. Normally, both biological effects and the judgements rendered about these effects are short-term. Secondly, necessarily viewed in a long-term perspective are effects attributable chiefly to the residues of pesticides whose biological consequences cannot be easily forecast. This second category of effects is more serious. Not only are these effects unpredictable, but they act at temporal, biological, and spatial distances whose routes of transfer and action are poorly known.

The latter-named set of problems may be summed up simply (see also figures 1 and 2):

1) Many pesticides persist and we cannot dispose of them.
2) They may cause unintended effects in place; usually these are populational phenomena (e.g., resistance, faunal displacement).
3) Their presence may occur at considerable distances from points of origin. Clearly, fluid transport systems (air and water flows) are chiefly responsible for dispersal.
4) Following dispersal of residues, differential magnification in biological systems may cause unintended and unexpected results.

Although one may describe the case simply and in spite of a large and increasing body of detailed literature, I strongly believe that we are grossly ignorant of the longer-term ecological consequences of past and continuing environmental contamination from persistent pesticides and other

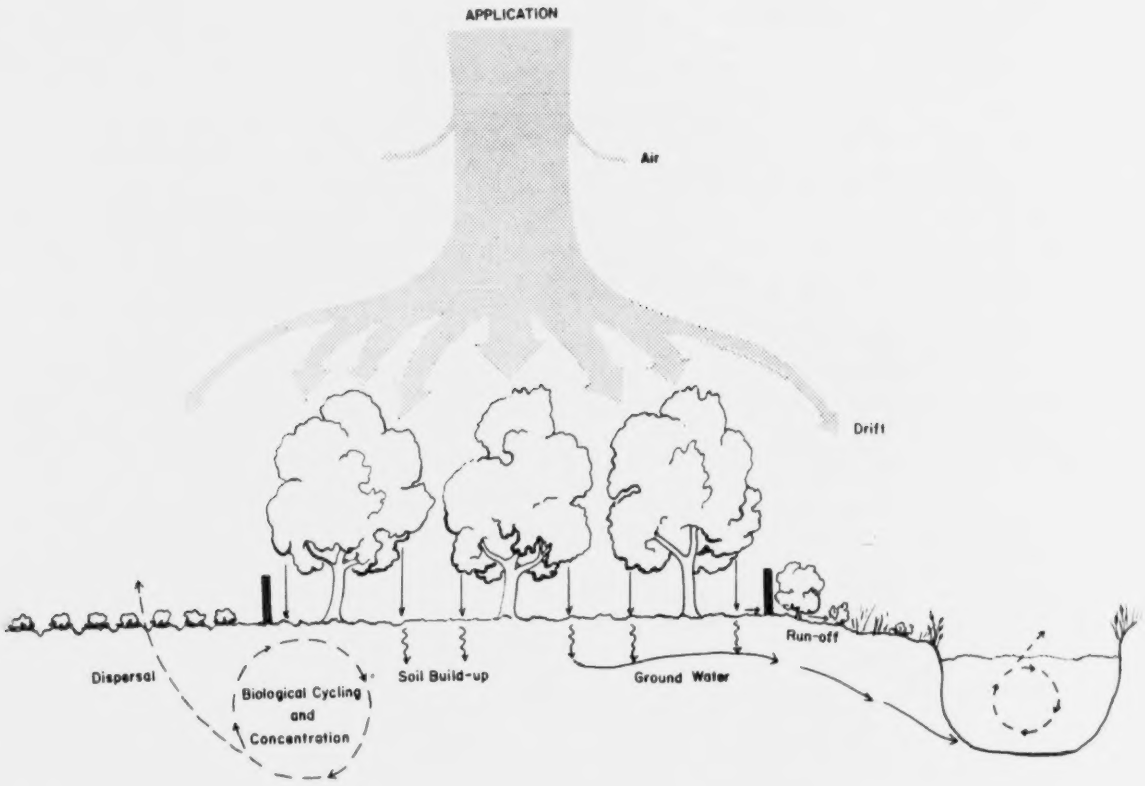
APPLICATION
Air
Drift
Dispersal
Biological Cycling and Concentration
Soil Build-up
Ground Water
Run-off

Figure 1. The General Case of Persistent Pesticide Kinetics. The larger fraction of spray goes to the intended area. A sizeable fraction drifts onto unintended surfaces. A small portion is carried into the atmosphere. Surviving residues at the surface may leach into water or enter the organic food chain where biological concentration begins.

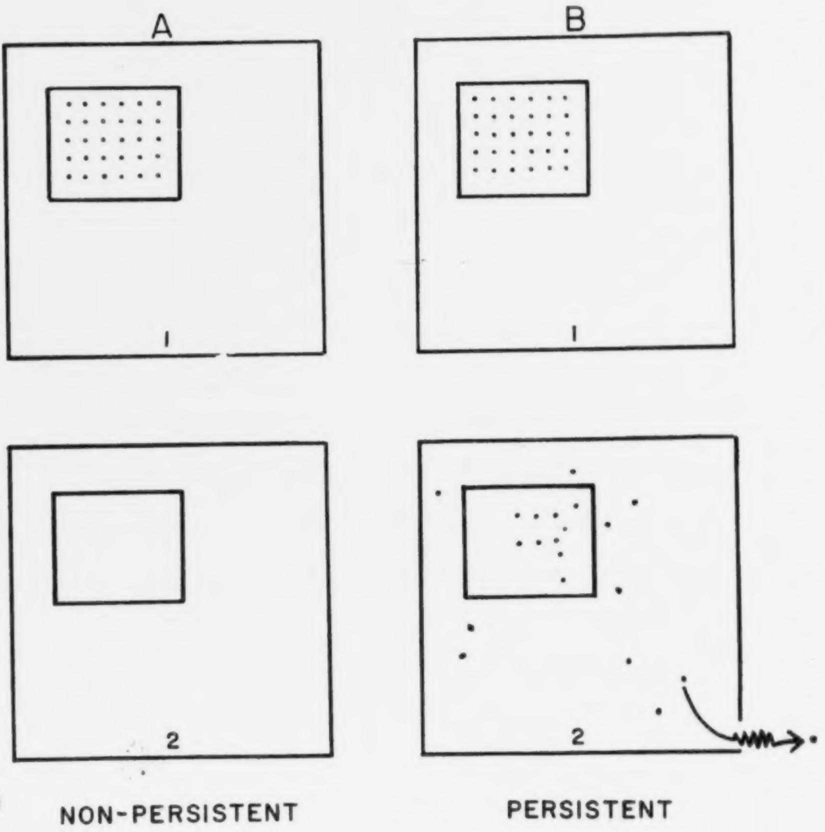
A
B
1
1
2
2
NON-PERSISTENT
PERSISTENT

Figure 2. A Comparison of the Fates of Persistent and Non-Persistent Pesticides. Time of application is indicated by "1", a later time by "2". The non-persistent pesticide (A) clearly degrades and "disappears." A fraction of the persistent pesticide (B) not only survives, but disperse from the area of application. (after N. W. Moore)

"hard" waste products of technological man. We have sufficient clues at the present to suspect that these consequences may, in time, be very large indeed. My personal suspicion is that "incidents of hazard" which we now report are symptomatic of much more serious ecologic damage currently being sustained.

I have elected to describe briefly four categories of ecosystem-pesticide residue relationships that I consider topical and significant. Although I have drawn heavily upon my experience with problems of this nature in the State of California, illustrations come as well from all parts of the globe.

THE FACT OF RESIDUAL OCCURRENCE

There is now no question that pesticide residues occur widely over the earth. Soils, water, flora, and fauna frequently have pesticide residues, chiefly DDT and its degradation products. Were it not for sophisticated analytical equipment only recently developed,[2] most of these residual amounts would have remained undetected.

The fact of residual occurrence is a very different thing from the judgment of biological significance. Yet we continue to be surprised at the places where we find residues -- such diverse points as flowing waters,[3] marine ecosystems,[4] remote Bermuda petrels,[5] aerial dust over continental areas,[6] aerial dust over open ocean,[7] and fish and wildlife.[8] In our studies in Clear Lake, California, we continue to find in plankton, fish and birds enduring high residual values in an area where persistent pesticides have not been used for a decade.[9] The listing could be expanded considerably.

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[2] Lisk, D. J. 1966, "Detection and Measurement of Pesticide Residues," Science, 154:193-198.

[3] Bailey, T. E. and Hannum, J. R. 1967, "Distribution of Pesticides in California," J. Sanitary Eng. Div., Amer. Soc. Civil Eng., Proc., 5510:27-43.

Nicholson, H. P. 1967, "Pesticide Pollution Control," Science, 158:871-876.

[4] Risebrough, R. W. 1969, "Chlorinated Hydrocarbons in Marine Ecosystems," IN Chemical Fall-out. Proc. 1st Rochester Conf. on Env. Toxicity, in press.

[5] Wurster, C. and Wingate, D. 1968, "DDT Residues & Declining Population in the Bermuda Petrel," Science, 159: 979-981.

[6] Cohen, J. and Pinkerton, C. 1966, "Widespread Translocation of Pesticides by Air Transport and Rain-out," IN Organic Pesticides in the Environment, Amer. Chem. Society, Adv. in Chemistry, ser. 60:163-176.

Studies in California provide a community appraisal of residual occurrences.[10] Samplings of 86 species of wildlife and the environments in which they are found allow these conclusions: near universality in tissue; near universality, but differing quantities, in waters, suspended materials, and bottom muds; more likely exposure in aquatic and wetland habitats; and greater concentrations in carnivorous forms.

One clear conclusion emerges: pesticide residues, probably increasing in amount, can be easily found wherever we choose to look for them. Yet, the prevailing attitudes of agricultural experts and regulatory officials run counter to that conclusion. As it should be, their concern is the intake of residues in human food. Note figures 3 and 4. They show loss or disappearance rates in soil and edible foods. But, do these residues truly "disappear?" The implication that "loss" means chemical degradation and loss of toxicity is incorrect. What we may more properly conclude is that significant fractions of these residues by no means disappear and, combined with biological magnification, pose continuing dangerous ecological problems.

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[7] Risebrough, R. W. 1968, "Pesticides: Transatlantic Movements in the Northeast Trades," Science, 159:1233-1236.

[8] Dustman, E. and Stickel, L. 1969, "Occurrence and Significance of Pesticide Residues in Wild Animals," Conf. Biol. Effects of Pesticides in Mammalian Systems, Ann. N.Y. Acad. Sci., in press.

Rudd, R. L. and Genelly, R. E. 1956, "Pesticides: Their Use and Toxicity In Relation to Wildlife," Calif. Fish & Game, Game Bull. No. 7, 204 pp.

[9] Herman, S. G., Garrett, R. L., and Rudd, R. L. 1969, "Pesticides and the Western Grebe," IN Chemical Fall-out, Proc. 1st Rochester Conf. on Environmental Toxicity, in press.

[10] Keith, J. O., and Hunt, E. G. 1966, "Levels of Insecticides in Fish and Wildlife," Trans. 31st N. Amer. Wildlife Conf., 150-177.

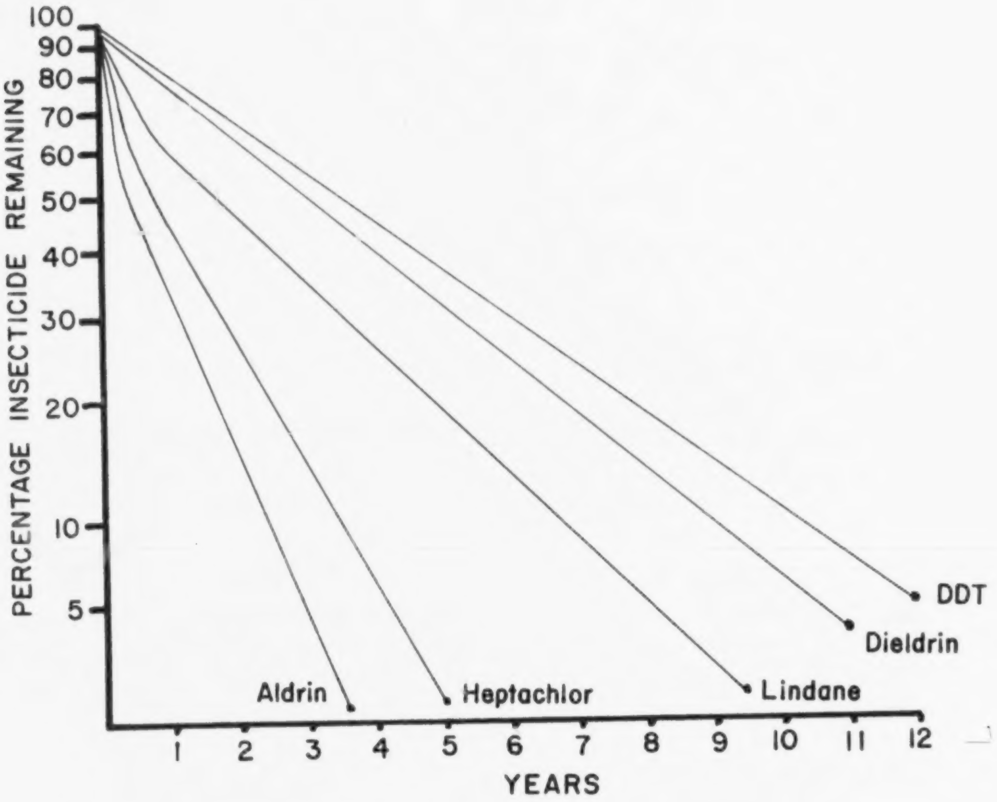

Figure 3. The Normal Method of Showing Persistent Pesticide Disappearance Rates in the Soil. Notice that total "loss" is expected and predicted on essentially a straight-line basis. The representation, common though it is, is ecologically naive. First, in both organic and inorganic environments, soils are among the poorest media for showing insecticide survival. Second, no indication is given of the survival and enhancement of residues in the living systems.

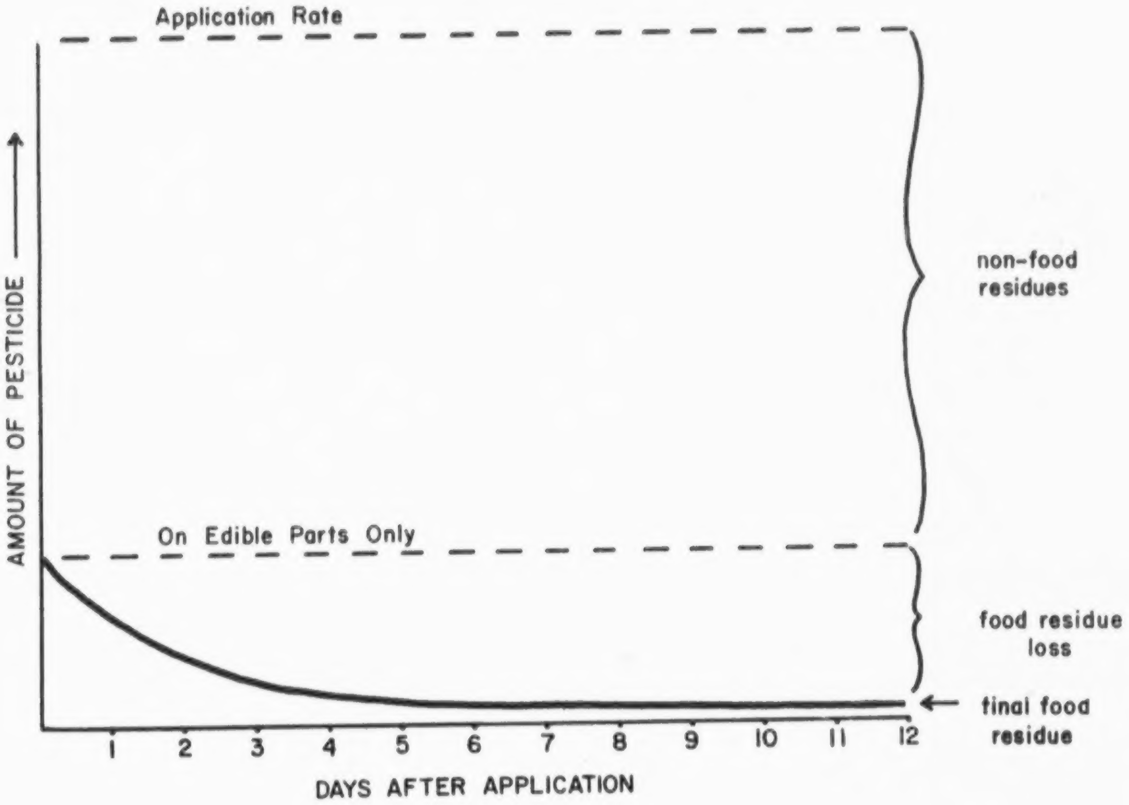

Figure 4. The Normal Manner of Representation of Surviving Food Residues on Human Foodstuffs. Important as this approach is for human welfare, it, too, is ecologically naive. The implication that pesticide residues no longer are significant because "tolerance limits" are not exceeded on the foodstuffs overlooks the ecologic fate of the much larger remainder.[11]

SYSTEMS OF RESIDUE TRANSPORT AND ENTRAPMENT

The references previously cited impute both physical and biological transfer systems to account for the spatial distribution of residues. In general, the transfer of residues in physical systems may be directly measured. Thus we can offer a variety of data in order to demonstrate that residues occur in aerial dust and smog, rainfall, in air far at sea, in ground and flowing water, and in soils at different depths and of different types. No one has yet conducted a full study of pesticide kinetics in natural ecosystems. We are attempting a microcosmic study of this sort at Clearlake, California.[12]

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[11] Crosby, D. G. 1964, "Intentional Removal of Pesticide Residues," IN Research in Pesticides, C. O. Chichester (Ed.), Academic Press, pp. 213-223.

[12] Herman, et. al., op. cit.

We can now judge generally that fluid movements --- air and water --- are primarily responsible for residue transfers over long distances. A recent report[13] shows how surprisingly far trace residues can be carried away from continental land masses (see Figure 5 below). But DDT had previously been found in such remote areas as Antarctica.[14] Such reports are now commonplace. The total amounts carried by fluid transport can only be estimated. For example, the discharge of pesticide residues from our Central Valley into San Francisco Bay has been estimated at almost two tons per year.[15]

Biological mechanisms in residue transfer are often inferred. Descriptions of amounts in tissues can, of course, be made. But, to assess transfer mechanisms a good knowledge of life histories of implicated species and of trophodynamics in entire ecological communities is required. Unfortunately, too often we do not have all the information needed for full assessment. Schematic representation

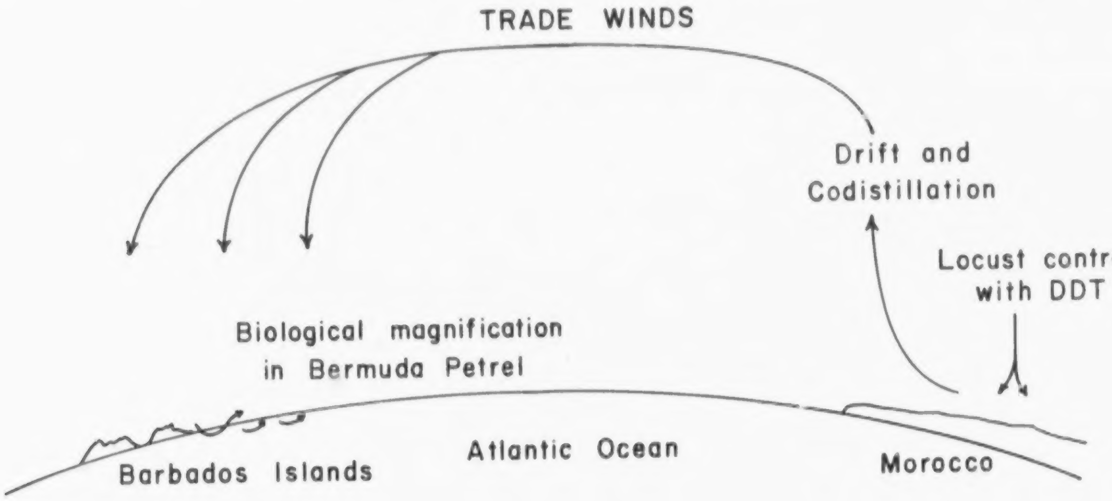

Figure 5. Aerial Transport of Residues and Subsequent Biological Magnification Reaching Toxic Levels in an Ultimate Consumer. This example is extreme, but generally describes how residues enter biological tissues in areas remote from points of application (cf Risebrough, 1968).

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[13] Risebrough, 1968, op. cit.

[14] George, J. and D. Frear, 1966, "Pesticides in the Antarctic," In Pesticides in Environment & Effects on Wildlife, (Moore, ed.) J. Appl. Ecol., Vol 3, sup:155-67.

[15] Bailey, T. and J. Hannum, 1967, "Distribution of Pesticides in California," J. Sanitary Eng. Div., Society Civil Engineers, Proc. 551:27-43.

of the biological and physico-biological systems involved in these assessments is provided in Figures 6 and 8. These figures describe our own studies at Clear Lake where our major goal is a refined description of such information. They show residue kinetics and the entrapment mechanisms that generally obtain in freshwater ecosystems. With only a slight ecologic distortion the samepathways in open ocean can be illustrated (see Figure 7).

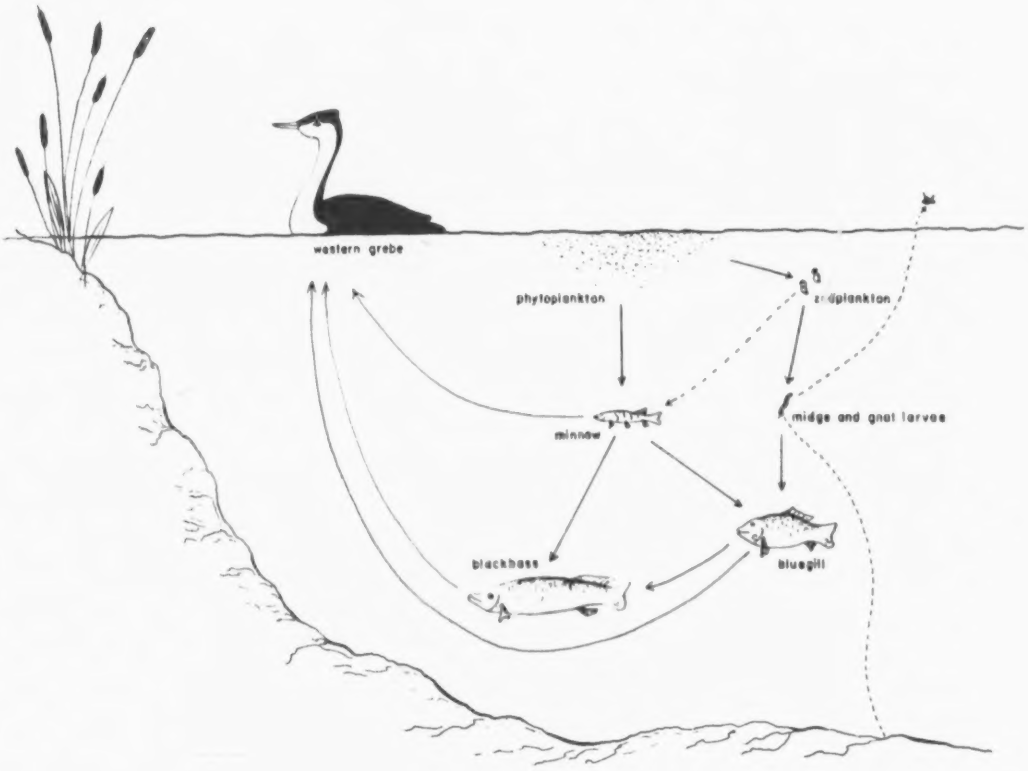

Figure 6. A Simplified Representation of Aquatic Foodchians at Clear Lake, California. Slow release of persistent pesticide residues from the surrounding watershed and the lake bottom enables the biological "capturing," storage and the magnification in the foodchain. As a general rule, it is the last link in the foodchain (the ultimate consumer) that shows toxic symptoms of concentrated residues.

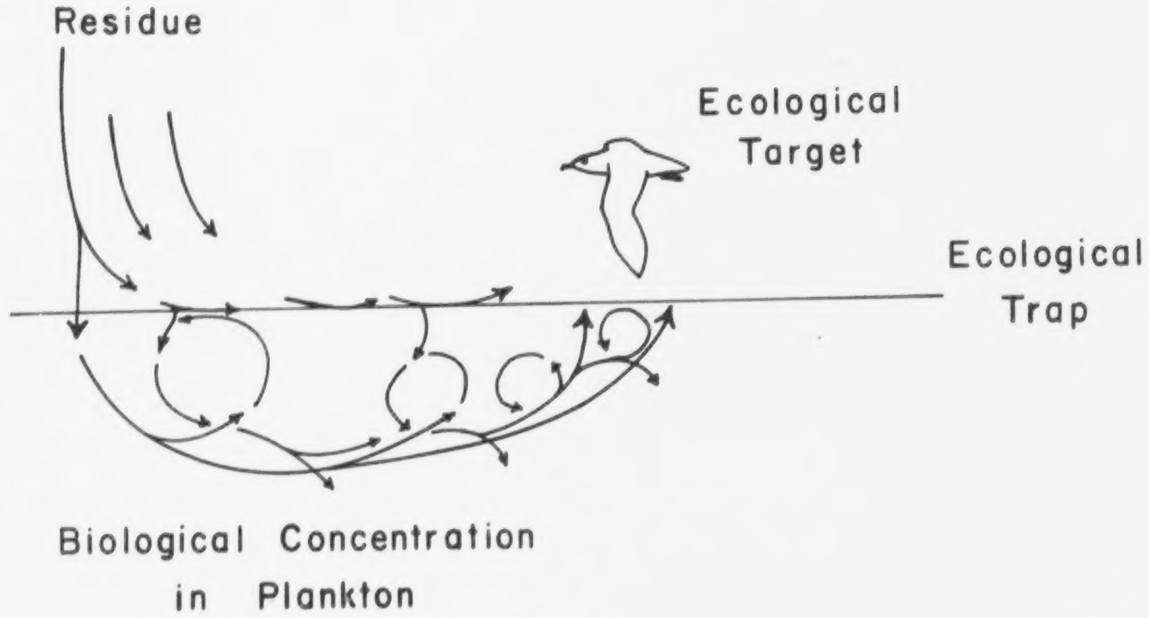
Residue
Ecological Target
Ecological Trap
Biological Concentration in Plankton

Figure 7. One means of ecological "entrapment" and confinement of pesticide residues. Airborne particles of pesticide striking a water surface do not disperse below the "skin." Rapid uptake by planktonic "environmental concentrators" ensures spatial confinement of residues to the top biological layers in which residue magnification occurs.

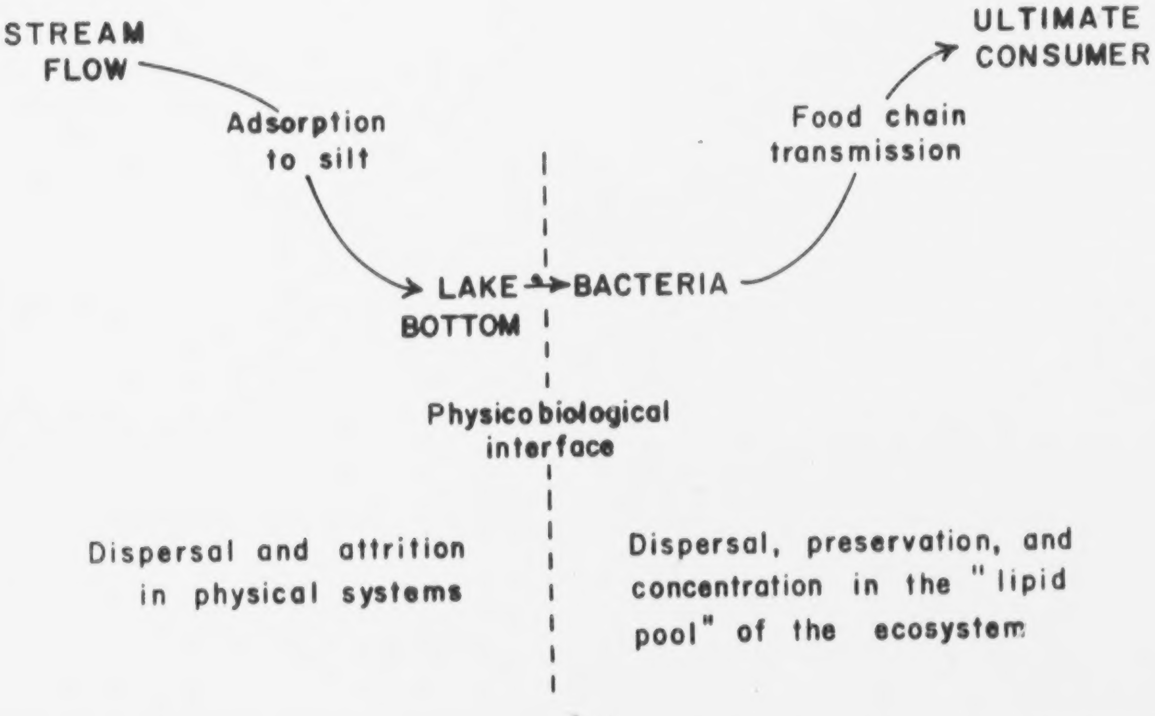
STREAM FLOW
Adsorption to silt
LAKE BOTTOM
BACTERIA
Food chain transmission
ULTIMATE CONSUMER
Physicobiological interface
Dispersal and attrition in physical systems
Dispersal, preservation, and concentration in the "lipid pool" of the ecosystem

Figure 8. Schematic representation of pesticide kinetics in lacustrine ecosystems. Residues disperse and degrade in the physical component but are entrapped, survive, and their amounts enhanced in the biological segment. The relatively inert lipid fraction amounts to an ecological preservative for these residue "fossils."

Pesticide residues in animal tissues have their source in an environment normally containing traces of residues. Initial entry into the animal food chain normally is by means of contaminated foods. This source must be essentially the only way that terrestrial animals acquire tissue residues. Contaminated foods among aquatic animals are also major sources of tissue residues, but are particularly important in secondary links in the food chain. Initial entry in aquatic food chains may derive from the tendency of pesticides to adsorb on suspended particulate matter and from filter-feeding organisms known to be environmental concentrators. There is some evidence as well that living organisms in environments in which sublethal amounts of residue are present may acquire residues directly through the gills, and skin[16]

Two serious areas of ignorance remain. The first concerns the physico-biological interface. How precisely are residual transfers made from an inorganic environment to a biological community? The second is the amount and nature of return residues to a biological community following death of contaminated tissues. In short, what is the nature of biological recycling of pesticide residues?

BIOLOGICAL MAGNIFICATION

"Capturing" existing residues occurs either by living environmental concentrators or by food-gatherers in a biological chain. Magnification or concentration of captured residues may occur by three methods. Physiological concentration occurs when residues are stored and accumulated by particular tissues within the bodies of individual organisms. A near "straight-line" relationship exists between lipid or fatty fractions of a tissue and the amount of residues contained. *Biological concentration* occurs in those instances in which residues are picked up directly through the skin or respiratory surfaces. This method is rather common in aquatic environments. *Trophic concentration* --- or food-chain concentration --- occurs simply because one organism depends upon another for something to eat. Stored residues, of course, accompany ingested foods and are assimilated and stored in the predator which, in turn, if eaten, passes along a larger amount of residues. All three methods of concentration lead to magnified quantities of residues in secondary consumers in food chains. Ultimate consumers, needless to say, are most hazarded.

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[16] Allison, D.T., Kallman, B. J., Cope, O. B., and VanValin, C, 1964, "Some Chronic Effects of DDT on Cutthroat Trout, USDI, Bureau of Sport Fisheries and Wildlife, Res. Report 64. 30 pp.

A great deal of study is currently being directed toward problems of biological magnification. I consider the reality of these forms of concentration in ecosystems established.[17] More inclusive and more detailed community studies characterize recent work as in Woodwell's *et al*[18] and our own studies.

At the same time, more attention is being given to differential abilities of species or trophic types to concentrate residues. In some instances, most notably in raptorial birds, declines in numbers seem to be clearly related to the presence of pesticide residues.[19] And in our continuing work at Clear Lake, high residue levels are clearly correlated with inhibition of reproductive success in Western grebes.[20] The rare Bermuda petrel clearly shows these residue effects on reproduction.[21] Yet, more dramatically, the total failure of brown pelicans to breed successfully on the coastal islands of California in 1969, is probably attributable to biological magnification of ecosystemic containment residues.[22] Although entire species populations of both invertebrates and vertebrates are declining because of environmental contamination, no one can yet provide evidence for the inhibited productivity of enitre ecosystems. There is a strong possibility that this is true.[23] and this possibility must be our most urgent concern.

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[17] Rudd, R. L. 1964, *Pesticides and the Living Landscape*, Univ. Wisconsin Press, 320 pp.

[18] Woodwell, G., Wurster, Sr. C. F., and Isaacson, P. 1967, "DDT Residues in an East Coast Estuary: A Case of Biological Concentration," *Science*, 156: 821-24.

[19] Hickey, J. J. (Ed.), 1969, *Pergrine Falcon Populations -- Their Biology and Decline*, Univ. Wisconsin Press, 596 pp.

[20] Herman, *et al*. *op. cit*.

[21] Wurster, *et al*, 1968, *op*. *cit*.

SIGNIFICANCE OF RESIDUAL CONTAMINATION

It is euphemistic to say that attitudes and interests differ regarding the significance of pesticidal effects. There has been, in fact, and continues to be a "pesticide controversy." Emotional as the controversy has become since Rachel Carson's Silent Spring, some definitive results have emerged from the controversy.

The first of these is simply an expanded pesticide technology that has yielded a very great deal of recent information. We need no longer question that persistent residues occur widely and are largely uncontrolled toxic wastes. A general picture of transport mechanisms is now in view. Several instances of complicated ecosystemic transfer are now well documented. Interest, financial support, specialized training, and an expanded awareness of environmental problems continue to insure better and closer study of the many problems involved.

Let me provide two illustrations of new information on questions that have plagued ecologists for a long time. One example concerns why declines in numbers of certain species of birds, particularly raptors, have taken place coincident with the increasing use and environmental contamination by chlorinated hydrocarbon materials. The loss of young, the decrease in clutch size, the decrease in egg-shell thickness, the increase in egg breaking in raptors (and very recently in brown pelicans) have been linked to an aberrant calcium metabolism. DDT and DDE (as well as PCB) have been shown to be powerful inducers of hepatic enzymes which degrade estradiol. Estrogenic hormones in female birds play an important role in calcium metabolism. Insecticide residues concentrated in tissue can now be shown to have altered the normal hormonal balance in wild species leading, unfortunately, to species-wide effects.[24] Representatives of at least three orders of birds seem affected in this manner. Without question, the list of affected species will grow. The remaining question is, "Will effects of this kind be limited to birds?" The answer is, "Quite probably not."

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[22] Risebrough, R. W. Reiche, P., and Peakall, S., Herman, S., and Kirven, M. N., 1968, Polychlorinated Biphenyls in the Global System, Nature, 220:1098-1102.

[23] Wurster, C. F. 1968, "DDT Reduces Photosynthesis by Marine Phytoplankton," Science, 159:1474-1475.

The second illustration rests on the question, "How do insecticide-resistant vertebrates affect the organisms that feed upon them?" Professor Ferguson and his students at Mississippi State University now provide the answer. In experimental studies, 95% of the vertebrate predators (11 species) died after consuming one endrin-resistant mosquito fish, or as the authors report, "Our findings show that the resistant mosquito fish tolerate endrin residues sufficient to kill potential predators several hundred times their own weight."[25] The ecosystemic efforts of such a conclusion could be staggering. Unfortunately, we don't have the complicated, expensive, and long-term studies to determine just how serious these effects are. Clearly, severe restrictions on pesticide use are called for to prevent general ecological catastrophe.

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[24] Hickey, J. J. and Anderson, D. W. 1968, "Chlorinated Hydrocarbons and Egg-shell Changes in Raptorial and Fish-eating Birds," Science, 162:271-273.

Peakall, D. B. 1967, "Pesticide-Induced Enzyme Breakdown of Steroids in Birds, " Nature, 216:205.

Simkiss, K. 1967, Calcium in Reproductive Physiology, Reinhold Publishers Corporation, New York.

Welch, R. M. Levin, M., and Conney, A. H. 1969, "Effect of Chlorinated Insecticides on Steroid Metabolism," IN Chemical Fall-out. Proc. 1st Rochester Conference on Environmental Toxicity, in press.

[25] Rosato, P. and Ferguson, D.E. 1968, "Toxicity of Endrin-Resistant Mosquito Fish to Eleven Species of Vertebrates," Bioscience, 18:783-784.

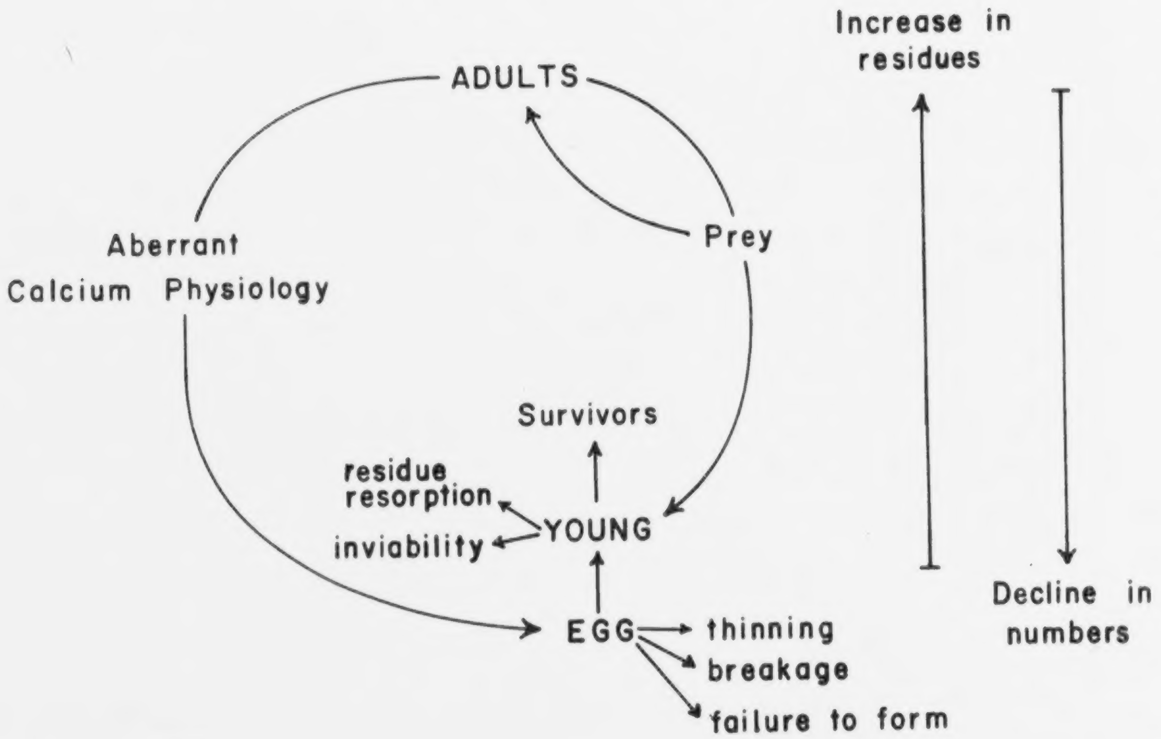
Increase in residues
ADULTS
Aberrant Calcium Physiology
Prey
Survivors
residue resorption
inviability
YOUNG
EGG
thinning
breakage
failure to form
Decline in numbers

Figure 9. A Simplified Drawing Illustrating the Physiological Mechanisms by Which Species of Raptorial and Fish-Eating Birds Must Decline. Numbers decline in the "ultimate" consumers as pesticide residue increases. The breakdown of estrogens affects the circulating calcium level in the blood, in turn affecting both the adult and the unhatched egg (cf Hickey and Anderson).

The second major event is a consequence of the increasingly accepted view that pesticide residues are a serious environmental hazard. This awareness has in 1969, resulted in important legislative actions. Sweden has placed a moratorium on the use of DDT and other chlorinated hydrocarbons for an extended period to determine whether environmental residue levels will abate. Both

Michigan and Arizona have restricted use considerably, and it is very likely that Wisconsin will shortly follow their example.

These illustrations reflect the fact that the critics of "hard" pesticides have not been unconvincing.

Perhaps yet more important is the third major recent event --- that is, to identify pesticide pollution as only a single facet of the much larger problem of environmental contamination by the ill-adapted waste products of technological man. Persistent toxic materials of whatever nature and origin tend to act in the same fashion in ecological communities. The recent demonstrations of residual polychlorinated biphenyls (waste products of paint and plastics industries) in the tissue of wild species, some far removed from land, is a case in point.

The parochial character of the pesticide debate must be discarded. Special interest arguments do not serve a present, enlightened, and responsible view of the problem. We should no longer depend upon production figures, national boundaries, guilt fixation, and the small percentages of areas treated, as justifications for continued use of persistent pesticides. The important thing is that use has been and is extensive; that confinement to areas of use is clearly impossible; and that major ecological consequences are already visible.

The use of persistent pesticides (and generally of non-degradable wastes) is no longer a parish problem. Even with total abandonment, the pressure of pesticidal "fossils" will continue to plague us for years to come.

ACKNOWLEDGEMENTS

I am indebted to Mr. and Mrs. S. G. Herman for both commentary and assistance with illustrations. I am indebted also to Dr. R. W. Risebrough for providing me with unpublished information, and to the U.S. Fish and Wildlife Service, Bureau of Sports Fisheries and Wildlife for support of the Clear Lake investigations.

DISCUSSION

QUESTION:

Are you in favor of the bill currently in the Legislature, the Nejedly-Sherman Bill, to ban the use of DDT and other persistent materials?

RUDD:

Obviously, the answer is yes; except that the bill needs some rewriting. I don't think it will pass.

QUESTION:

I have wondered if the present system of residue monitoring actually serves its purpose in environmental protection. I don't think so. Comment?

RUDD:

Yes, very good point. In other words, we use residue tolerance levels, tolerance thresholds, etc., in order to show important effects at trace amounts. That is, in vitamin level amounts, essentially. And the answer is, of course, it's a ridiculous system! And it's just in that same sense that we now spend millions of dollars to monitor the environment. To monitor for what? I just illustrated with one slide that monitoring is directed completely toward the wrong things. Monitoring in soils! What they should be monitoring is the living component of the environment.

I do have one question here that has to do with this --- unfortunately, people who mouth off on such issues sometimes are quoted --- and the particular quote is from the dust jacket of a book by Congressman Jamie Whitten entitled That We May Live. The statement in question is (and, unfortunately, I think I did make it because I disagree strongly with Congressman Whitten), "A book by Congressman Whitten entitled That We May Live quotes you, 'Let me state emphatically that those of us with close knowledge of production and pesticidal practices have never been truly against pesticides; nor was Rachel Carson.'" In answer to this, of course, is that I had said it in the Christian Science Monitor a few years back, and that's actually the case. I don't think that it's a paradoxical thing at all. I'm not against pesticides. I am, however, in favor of the control of man's wastes and the proper usage of products of technology. And then the book does, of course, say something about the beneficial effects of pesticides; and I wouldn't argue this, either, except that I think the judgements made in the book are short-term.

QUESTION:

Could you estimate how long DDT does last in the environment?

RUDD:

What I'm suggesting to you is a fairly new thought that some of us are developing; that is, that it doesn't die. It doesn't have a half-life. It persists and it's going to stay with us. For example, if we outlaw it and its export abroad (and it will happen because there are two states now that have actually outlawed its use or restricted it in some fashion; it will happen in Wisconsin shortly; it has happened in Sweden; we're attempting to do it this year in California) I suspect that these effects I've been talking about will continue for two to three decades. And they may very well go on indefinitely. The Clear Lake example --- one reason, of course, why we're funded to study it --- is because something's happening that's not supposed to happen. These materials are supposed to go away. We wanted them to go away; they're supposed to; and they don't. As I say, it's been twelve years since anybody's put anything up there like that. Now, to me, this is a horrendous thing. I think DDT will survive indefinitely.

QUESTION:

Since the food-chain of man is essentially short, could we expect to have, necessarily, the same effects through this biological magnification method?

RUDD:

This was answered, in part, by an answer to a previous question related to the residue levels. That is, if you're going to get low level effects, trace effects, you may as well not worry about how many parts per million there are. That's one answer. The other thing is --- and this wasn't brought out earlier --- that in man, although we have eleven or twelve parts per million on the average in our tissues, there are correlations with other kinds of exposure. Some people are prone to store it. For example, there are recent studies showing that there is a definite relationship between cirrhosis of the liver and tumors of the liver. And this is correlated again with the residue levels that happen to be very high. Another thing that is not greatly advertised, I think the figure of twelve parts of a million came up this morning in the, shall we say, American fat, but it's much higher in other places. In India it's on the order of 46 parts per million and in Israel it's about thirty-odd. So, it isn't a uniform thing. And, incidentally, those kinds of residue data, unless you believe in some sort of racial difference, deny what a prominent public health servant stated in this country is a potential plateau of twelve parts per million. It can go beyond this so-called plateau.

QUESTION:

Is there some way to build into the chemical structure of DDT and other chlorinated hydrocarbons the capacity for them to degrade or destroy themselves after use?

RUDD:

I don't know the chemistry of it. I would only say this, anything that technical man makes, he should, in some fashion, arrange to destroy. And I assume that this may be done chemically. It is done, in some part, by natural means; and I include plastics, coke bottles, automobiles, or anything else. I don't limit it to DDT, certainly, because waste is our biggest hazard outside of population.

QUESTION:

Can pesticide residues still coming into Clear Lake be prevented from entering the Lake's food-chains?

RUDD:

No, because the amount that comes into the Lake comes from "fossils" that are already present in the argicultural watershed. It comes from the pear orchards and the alfalfa fields and so on, and it leeches in at a known and measurable rate. There was half a million pounds of DDT applied to that watershed in a seven-year period before use was stopped. And about 120,000 pounds of DDT was applied in the Lake itself. Well, we'll say that's three-quarters of a million pounds --- as a rough guess, and it's only a guess. I would say that there still are 100,000 pounds of toxic materials in that watershed. It's still there to plague us.

CONTROLLED ENVIRONMENTS FOR PLANTS IN RESEARCH - A CRITIQUE, A CONTRIBUTION, AND FUTURE PROSPECTS

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University of California at Davis, California

SUMMARY

Glasshouses have limited ranges of economic temperature control for research. Artificially-lighted growth chambers, while well-adapted to some particular problems, have severe limitations in regard to large plants, uniformity, intensity and quality of light, temperature range and uniformity, and costs of initial installation, maintenance, and operation. A new design of a room that rotates to face the sun has demonstrated the utility of an insulated large room that may be adapted to large plants of agricultural importance. Sunlight, at intensities averaging the equal of outdoors and more uniform over the day, offers a more natural environment with horizontal air flow and a wide range of controlled temperatures available.

In this room and in its stationary forerunner many species of plants have grown well. Its initial cost per square foot of useful space is less than that of an artificially-lighted chamber by a factor of three; and in sunny locations, its operational cost in power is less than 10% of the corresponding value for artificially-lighted chambers in typical research applications; the corresponding figure per light unit is often less than 1%. Useful modifications of these rooms for special purposes might include: 1) focused incandescent light to supplement sunlight, 2) provision of photoperiod control by the use of curtains or dark space to which plants may be moved, 3) atmospheric composition control with possibilities of pollution studies as well as enrichment with CO_2 for more rapid growth and quicker completion of experiments, 4) root temperature control, 5) quarantine areas for disease control, 6) use as an outside environment for smaller enclosed systems with very delicate controls obtainable at minimum cost, 7) very large area for large populations, 8) air dried for low humidities, and 9) use of native deep soil for extensive root systems.

Those of you who attended this conference yesterday are well aware that the population problem is immanent now and that the shortage of food, a problem which has long been present in many parts of the world, is just around the corner for us in the United States.

Our food supply is dependent upon plants. In spite of other possibilities in the distant future, this dependency upon our agricultural plant species is likely to continue for many years. The population problem will not be solved at once; this will take time. In the meantime, we should alleviate food shortages by more research into the physiology of our crop plants. We need to know more concerning their environmental limitations and optimum conditions for production, as well as genetic potentialities of new or untested strains or species. Such studies have long been in progress as a prime assignment of our state agricultural experiment stations. They have employed outdoor plots of ground, glasshouses (commonly called "greenhouses" here), and more recently, artificially-lighted growth chambers or rooms with regulated temperatures for growth of plants under test conditions. I intend to offer a brief critique of these methods, then to discuss a recent contribution that provides improved conditions, and finally, to suggest some future modifications for more specialized purposes.

Outdoor plots, while more useful for many purposes, have the disadvantages of soil heterogeneity and dependence upon weather conditions which are never the same from year to year. Moreover, they are often at a considerable distance from the experimenter's headquarters. Many years may be required to solve a comparatively simple problem and some problems prove to be impossible to solve by this method.

Glasshouses are essentially heat traps for solar energy. The effective admission of light and radiant heat from the sun results in accumulation of heat because absorption of radiant energy converts short-wave energy to long-wave energy which glass does not transmit outward. In warm weather, whitewash is often used to greatly reduce admission of solar energy into the glasshouses. This defeats the purpose for which the glasshouse was built, namely to admit sunlight for plant growth under protected conditions. Thus, glasshouses, having no insulation, are most effective in colder seasons but are often useless in warm weather or, at most, offer a very limited range of temperatures at a level of economic operation.

During the past twenty years, there has been a rapid development of commercially available artificially-lighted chambers for growth of plants under controlled conditions. The smaller of these are the reach-in types and the others permit the operator to walk in. Some are built as modules that may be united together to form larger units. In a recent issue of Guide to Scientific Instruments,[1] 19 manufacturers of such chambers are listed. Although some units may be custom-built for particular problems, all have severe limitations for large plants such as those that are of more common interest to agriculture:

1. In relation to light, intensity often limits the rate of photosynthesis and, hence, of growth. Fluorescent light cannot be effectively focused and intensity is reduced rapidly as the distance from the fluorescent tube increases. While intensity may be high very close to the tube, for most species of agricultural significance, the entire plant cannot be exposed to this intensity. Moreover, tubes deteriorate with operation and require separate control of temperature for efficient output of light. Quality of fluorescent light is not optimum for plant growth. Such tubes must be supplemented with incandescent light to provide sufficient red light and the high intensities of the mercury lines complicate the spectrum. Uniformity of intensity over the plant area, so important with low intensities, is another problem with small areas of this type.
2. Temperature ranges available are often limiting, especially when all lights are on. Uniformity of temperature is often satisfactory for comparatively small areas, although the use of large pots may obstruct the air flow (usually vertical, from the bottom) to cause temperature "shadows" in the volume occupied by the plant above the pot in which it grows. Minor changes in pot arrangement may affect

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[1] Science, 162-A (3856 A), 100, November 26, 1968.

the temperature of other areas considerably.

3. Costs are high; they include capital costs of the chamber with its equipment and controls, as well as price of installation, maintenance (especially of light bulbs), and electric power for operation.

For research purposes the sunlit phytotron unit, or solatron, offers many advantages. The rooms that I shall describe were developed as a result of effort initiated some 12 years ago at the University of California at Davis to control the temperature of large rooms suitable for the growth of large plants in the presence of high intensity sunlight. They resulted from the experimental work of myself and numerous members of the Agricultural Engineering Department, notably Professors L. W. Neubauer and S. M. Henderson.*

Our objective was to provide a wide range of temperature control in the presence of maximum intensities of sunlight in large insulated rooms at reasonable costs for capital and operation. From this series of experiments in design, both stationary and rotating models were developed. The latter rotates to face the sun continually during the day and offers the best opportunity for sunlight intensity to exceed saturation values for photosynthesis. If saturation intensities are exceeded during most of the day, minor fluctuations during the day do not influence other processes in plant life and the effects of other factors, such as nutrient requirements, temperature, humidity, disease, and heredity, may be more effectively studied. Saturation values of light intensity for whole plants (as opposed to isolated leaves) have not been reliably obtained for many species. Briefly stated, the stationary plastic room admits an annual average of 50% of outdoor sunlight and the rotating model 100%, as measured by a horizontal light meter.

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*The staffs of both the Agricultural Engineering and Plant Service shops at UC Davis constructed all of our designs; acknowledgements to numerous people are given in our publications. Much of the early instrumentation was provided by funds from the National Science Foundation (Grant No. G-13525).

Figure 1[2] shows the stationary unit facing south with insulated walls and light-transmitting double-pane, clear plastic roof, and windows on three sides. It has a cement floor with drainage, piped water, and room for benches and other facilities of the usual glasshouse. Four sprinklers at the apex of the roof go on for a few minutes daily to remove the dust from the roof.

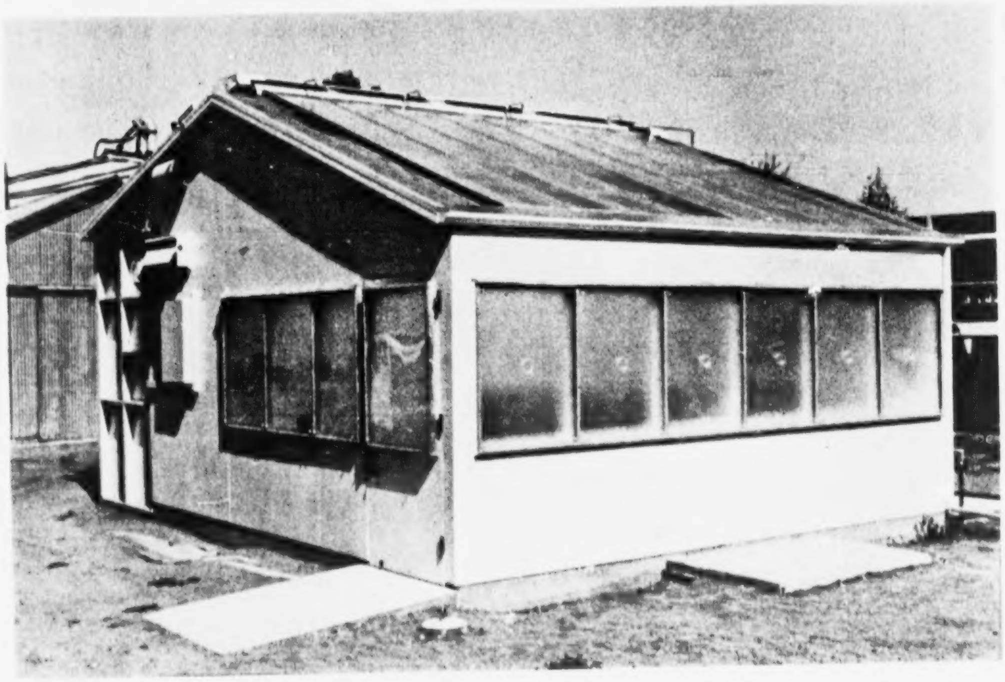

Figure 1

I will emphasize the rotating model shown in Figure 2[3] on the following page which is of similar size. The plant space is 12x18 ft. in area and 8 to 13 ft in height. The entire structure is 20x20 ft. overall. Side windows are not

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[2] Zscheile, F. P., S. M. Henderson, A.S. Leonard, and L. W. Neubauer, 1963, "Phytotron Modification Admits More Sunlight Through Plastic Panels, Calif. Agriculture, 17 (1), 10-11, January.

[3] Neubauer, L. W. and F. P. Zscheile, 1966, "Rotating Solatron Receives More unlight for Plant Growth," Calif. Agriculture, 20 (1), 4-5, January.

Neubauer, L. W., and F. P. Zscheile, Jr., 1968, "A Phytorotor That Rotates to Admit Maximum Sunlight," J. Ag. Eng. Res., 13 (3), 266-279, July-September.

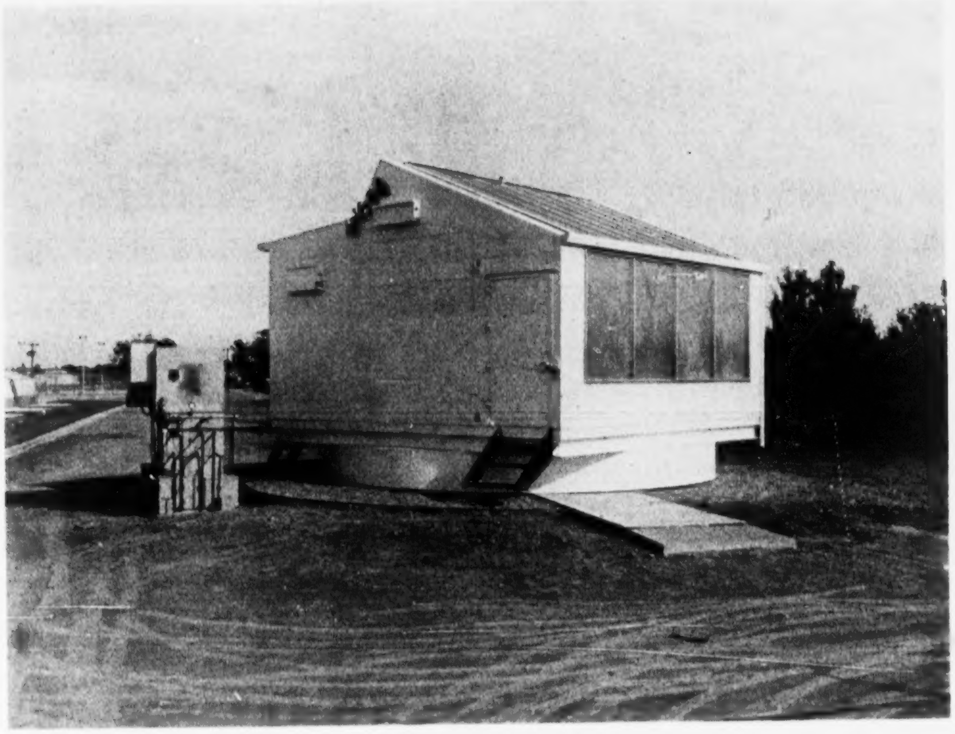

Figure 2

needed because the front windows always face the sun. They are also of maximum size. The water-cooled tower for removal of heat from the refrigerant is at the left of the room. Figures 3-11 show various stages in the room's construction. In Figure 3 is the cement block foundation with railroad rail on top and stairway in the foreground.

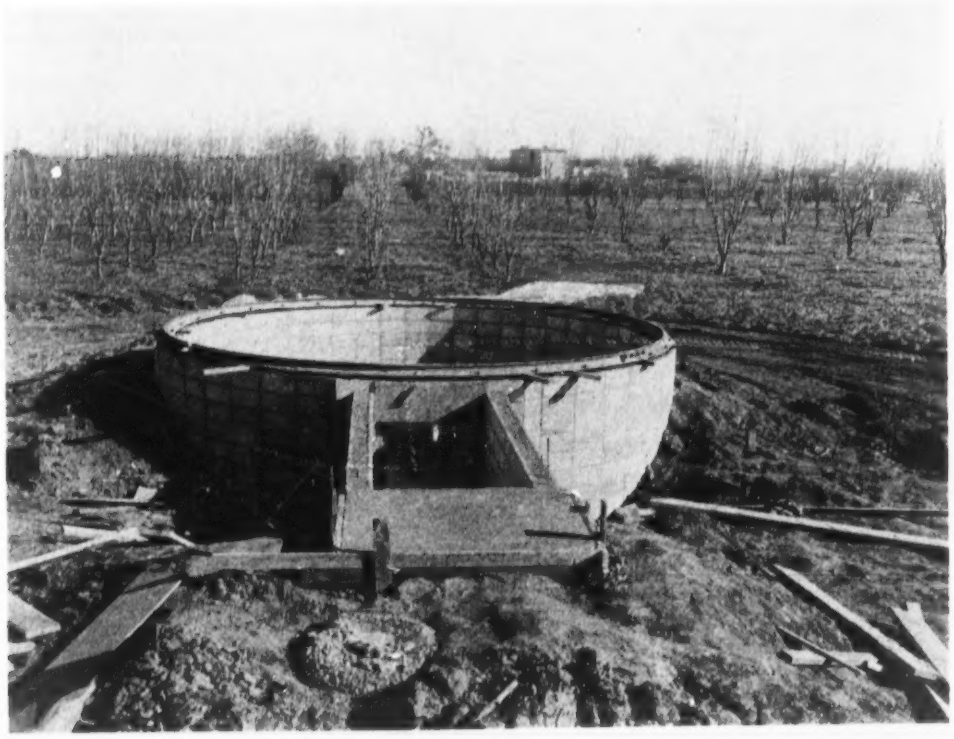

Figure 3

Figure 4 shows the frame of steel I-beams assembled on the eight wheels. Figure 5 shows the frame resting on the rail.[4]

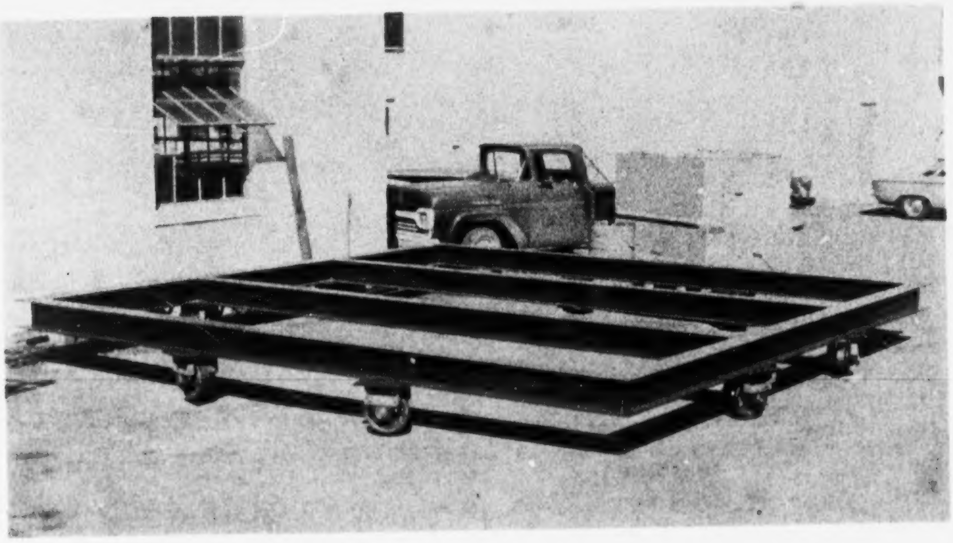

Figure 4

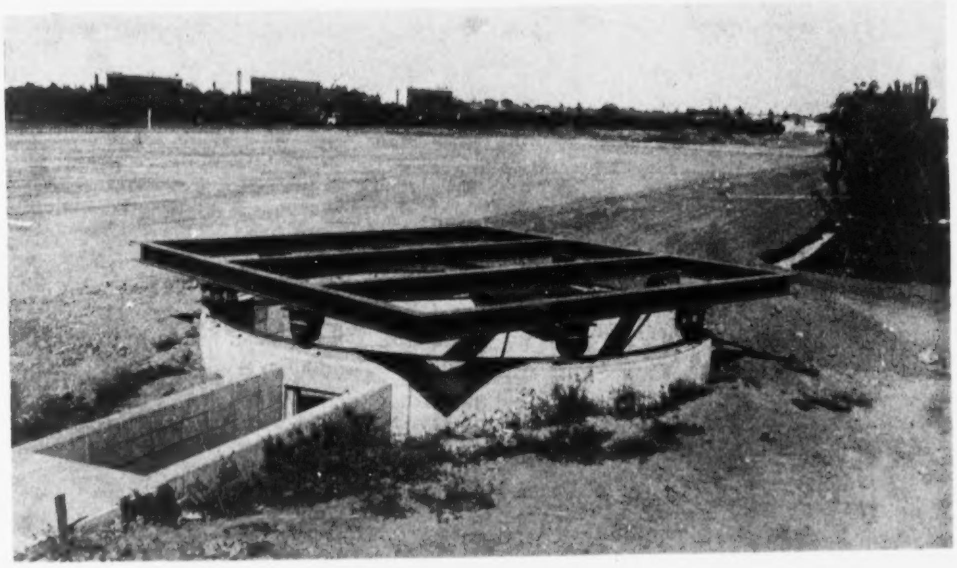

Figure 5

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[4] Neubauer, et al., 1966, op. cit.
Neubauer, et al., 1968, op. cit.

In Figure 6[5] one may see the driving mechanism hanging from the frame, driven by a 1/2 h.p. motor acting through a 672,000:1 reduction gear to give motion to an axle connecting the two opposite drive wheels (one in left center). Figure 7 shows the cement floor on the steel frame with bolts for anchoring the wooden structure to the floor.

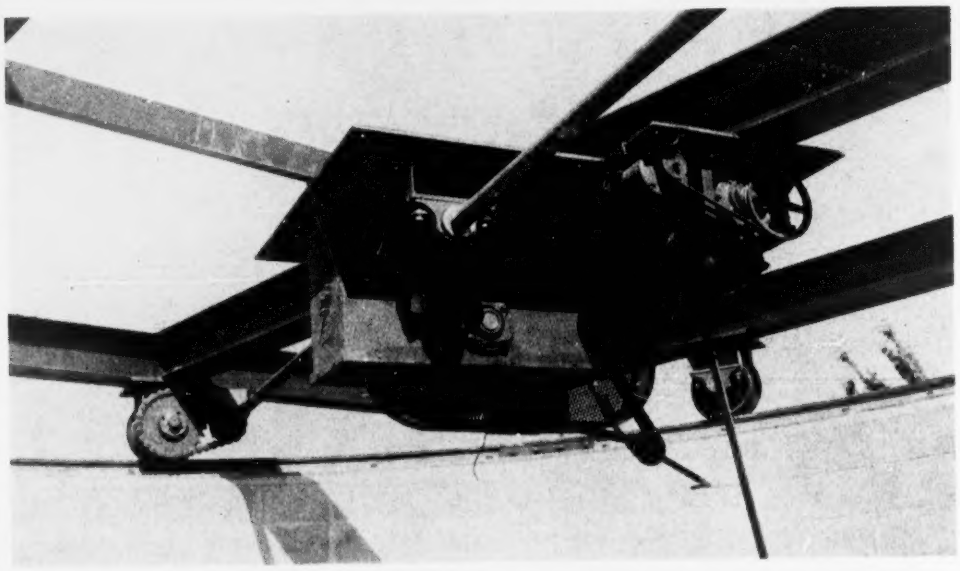

Figure 6

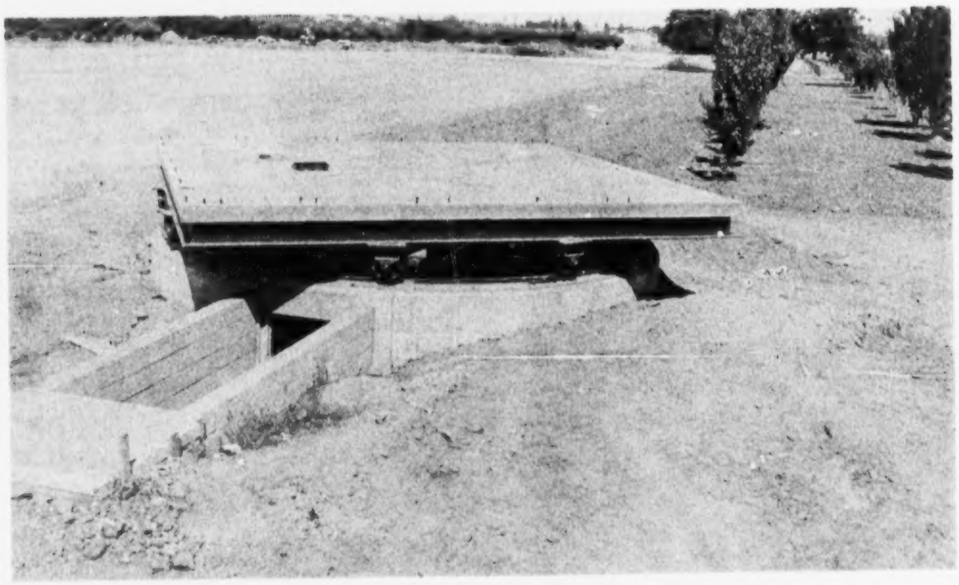

Figure 7

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[5] *Ibid.*

Figure 8[6] shows the floor plan with plant space at the bottom, air-conditioning equipment (cooling coil, heater strips, humidifier, and fan) at the top; arrows indicate the direction of air flow. Figure 9 demonstrates the standard type of wooden construction for insulated walls; the channels for air flow may be seen at the left before they are covered with a pegboard. (See next page)

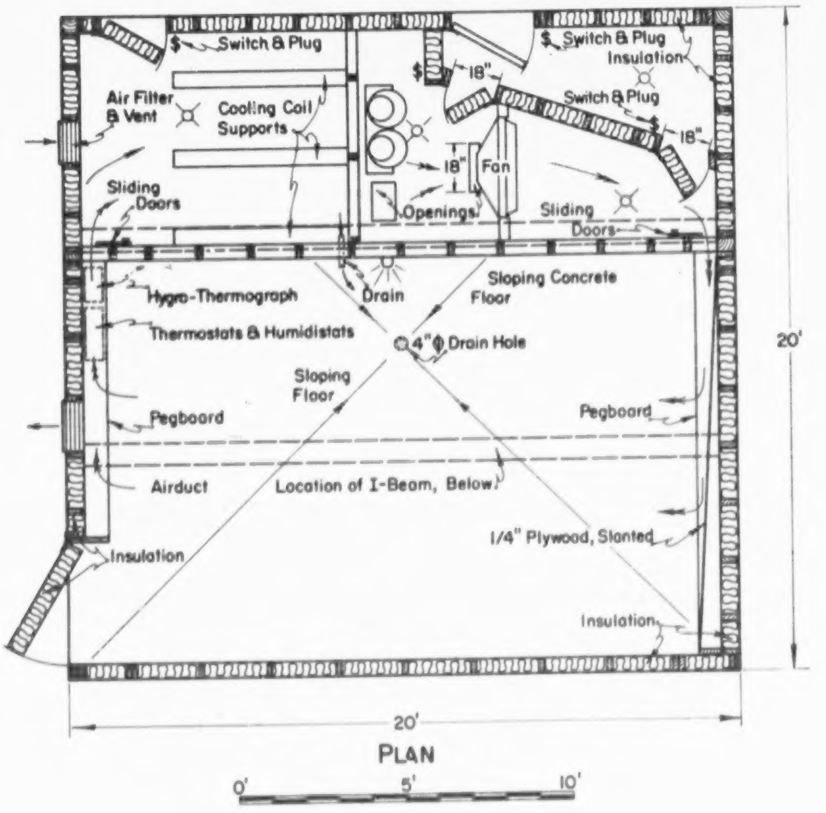
$ Switch & Plug
$ Switch & Plug
Insulation
$
18"
Switch & Plug
18"
Air Filter & Vent
Cooling Coil Supports
18"
Fan
Sliding Doors
Openings
Sliding Doors
Hygro-Thermograph
Drain
Sloping Concrete Floor
Thermostats & Humidistats
4" ϕ Drain Hole
20'
Sloping Floor
Pegboard
Pegboard
Airduct
Location of I-Beam, Below
1/4" Plywood, Slanted
Insulation
Insulation
20'
PLAN
0'
5'
10'

Figure 8

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[6] Neubauer, _et_ _al._, 1968, _op._ _cit._

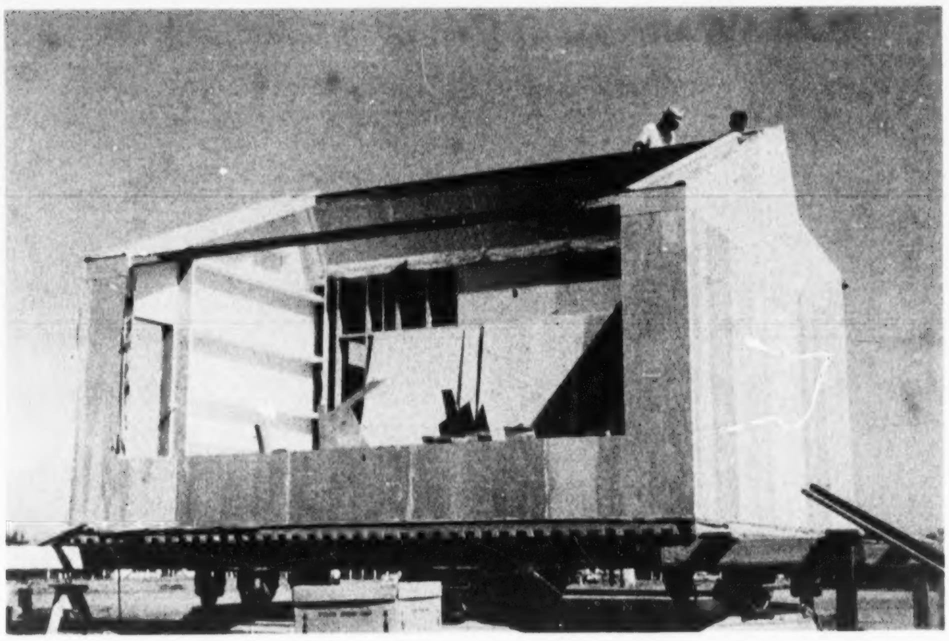

Figure 9

Figure 10 shows the aluminum supporting beams for the plastic (Plexiglas) windows in place as is the pegboard on the wall for equalization of air flow.

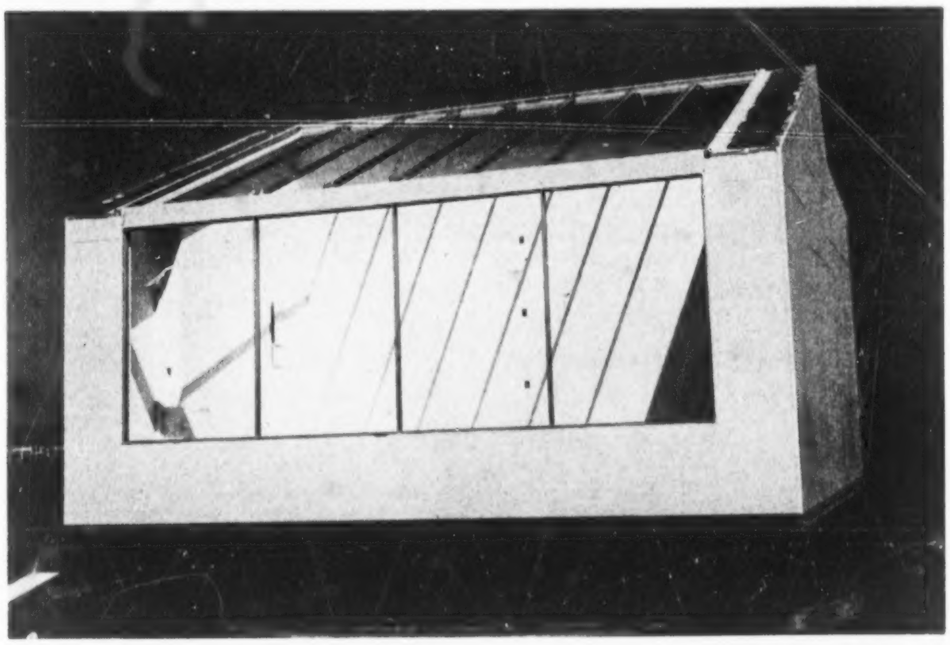

Figure 10

Figure 11, shown on the following page, depicts the structure when the windows are complete and a metal skirt is in place (but not painted) around the foundation but supported by the frame to protect the basement equipment (compressors, fan motor, electric controls, etc.). Figure 12[7] shows steps which lead into the plant room where sugar beets are growing in cans on the benches. The photocells for control of motion are seen as black objects in the upper left corner. One cell, oriented toward the sun, controls the

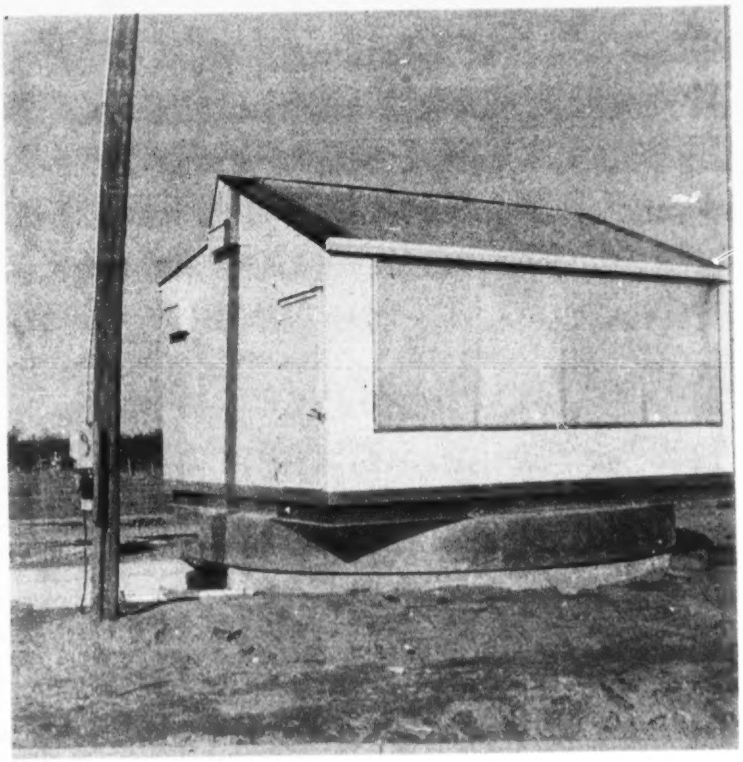

Figure 11

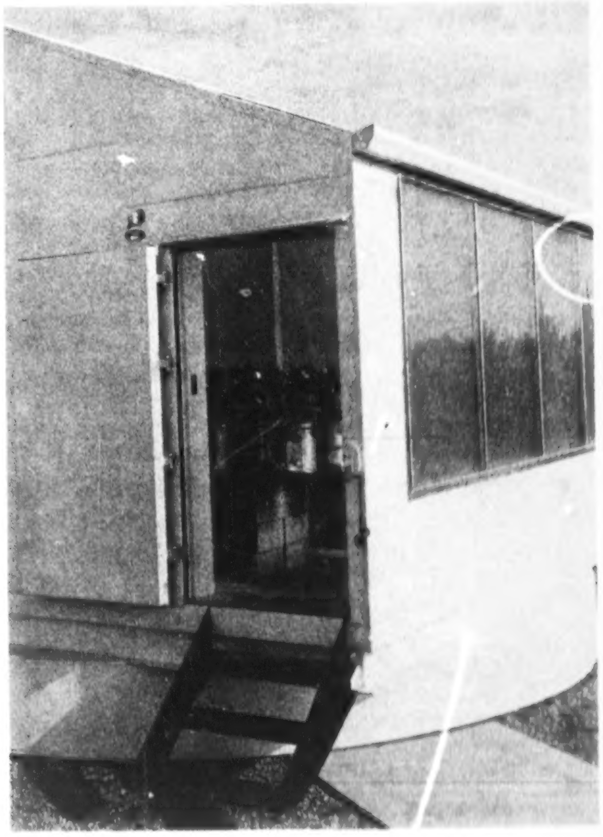

Figure 12

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[7] Neubauer, et al., 1968, op. cit.

motion when the sun is bright; another cell points at nearly right angles to the right of the sun, adjusted in position to receive light if the sun moves ahead of the room during a period of cloudiness; the third cell points upward and causes reverse motion of the room when darkness follows sunset. Controls near the track stop the reverse motion when the room faces the approximate location of the sun at sunrise.

This room permits growth of large plants under more natural conditions than other facilities with controlled and reproducible temperatures, with sunlight averages approximately equal to those outdoors but with a more uniform intensity over the day and with horizontal air flow. Figure 13[8] shows the air flow system of all our designs; it may be stratified if desired, with

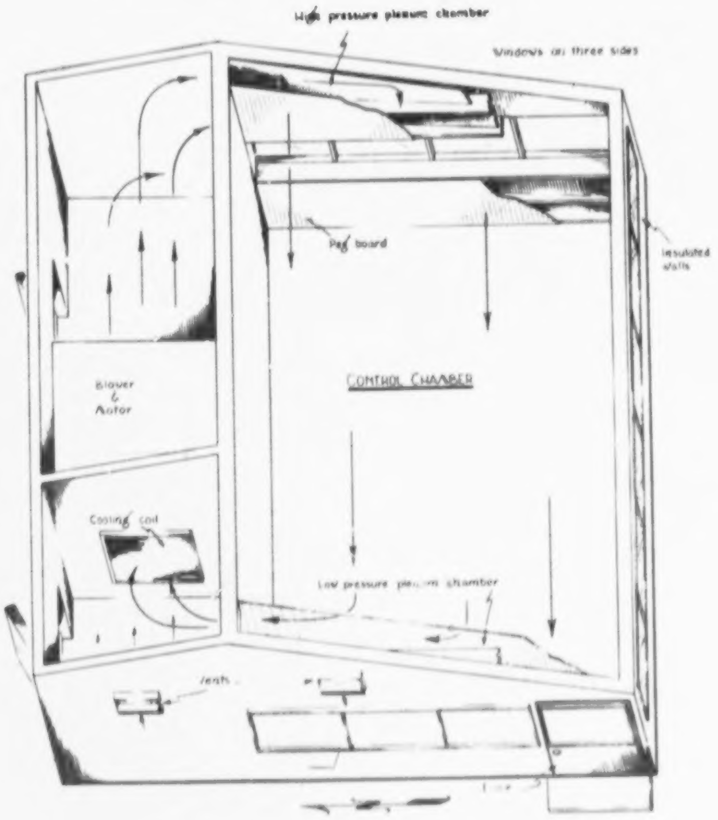
High pressure plenum chamber
Windows on three sides
Peg board
Insulated walls
CONTROL CHAMBER
Blower & Motor
Cooling coil
Low pressure plenum chamber
Vents

Figure 13

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[8] Zscheile, F. P., Jr., and L. W. Neubauer, 1967. Light Transmission Through Plastic Panels in a Sunlit Phytotron Unit," Journal of Agricultural Engineering Research, 12 (2), 94-109, April - June.

different speeds at different levels above the floor. We find a velocity of 30 ft/min or 0.34 m.p.h. suitable for good temperature control; this speed gives 1.7 changes of air per minute for the room. The temperature range available in this room is <40° to> 120°F., simultaneously with bright sunlight inside and high summer outdoor temperatures. A time clock controls the changes between day and night temperatures and, of course, offers a great range of variation. Temperature changes may be rapid (20° F or more per hour) if desired and freezing temperatures could be available if defrost equipment were added to the cooling coils. The temperature variation at the outlet side of the growth room is ± 1-1/2°F and across the room the differential may be 4 to 5-1/2°F during cycling. Heating and refrigeration never oppose each other[9] and sunlight often provides needed heat. Fresh air is admitted by regulation of the vents shown on the upper left wall (Figures 2 and 13).

Figures 14 through 18[10] as well as Tables 1 and 2 indicate the admission of sunlight to the rotating room. All measurements were made on clear days with the sunlight illumination meter used previously.[11] Here we distinguish between light intensities as measured by horizontal light meters (the customary way of measuring solar intensities) and those obtained by orienting the meter for maximum value; outdoors this would be directly at the sun in clear weather but indoors this would depend upon the location in the room. We consider the maximum value more meaningful from the plant's viewpoint, since its leaves are often randomly oriented or may be oriented toward the sun. Diffuse light, as admitted by the cosine filter, was included. The Figures 14 and 15 shown on the following page indicate the horizontal indoor intensities above outdoor values at lower solar elevations characteristic of

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[9] Henderson, S. M. and F. P. Zscheile, Jr. 1967, "A Simple Temperature Control for Phytotrons," J. Agr. Eng. Res., 12 (3), 233-37, July-September.

[10] Neubauer et al., 1968, op. cit.

[11] Zscheile, F. P., Jr., S. M. Henderson, A. S. Leonard, L. W. Neubauer, and S. J. Sluka, 1965. "A Sinlight Phytotron Unit as a Practical Research Tool," Hilgardia, 36 (14), 493-565, September.

Zscheile, F. P., Jr., et al., 1967, op. cit.

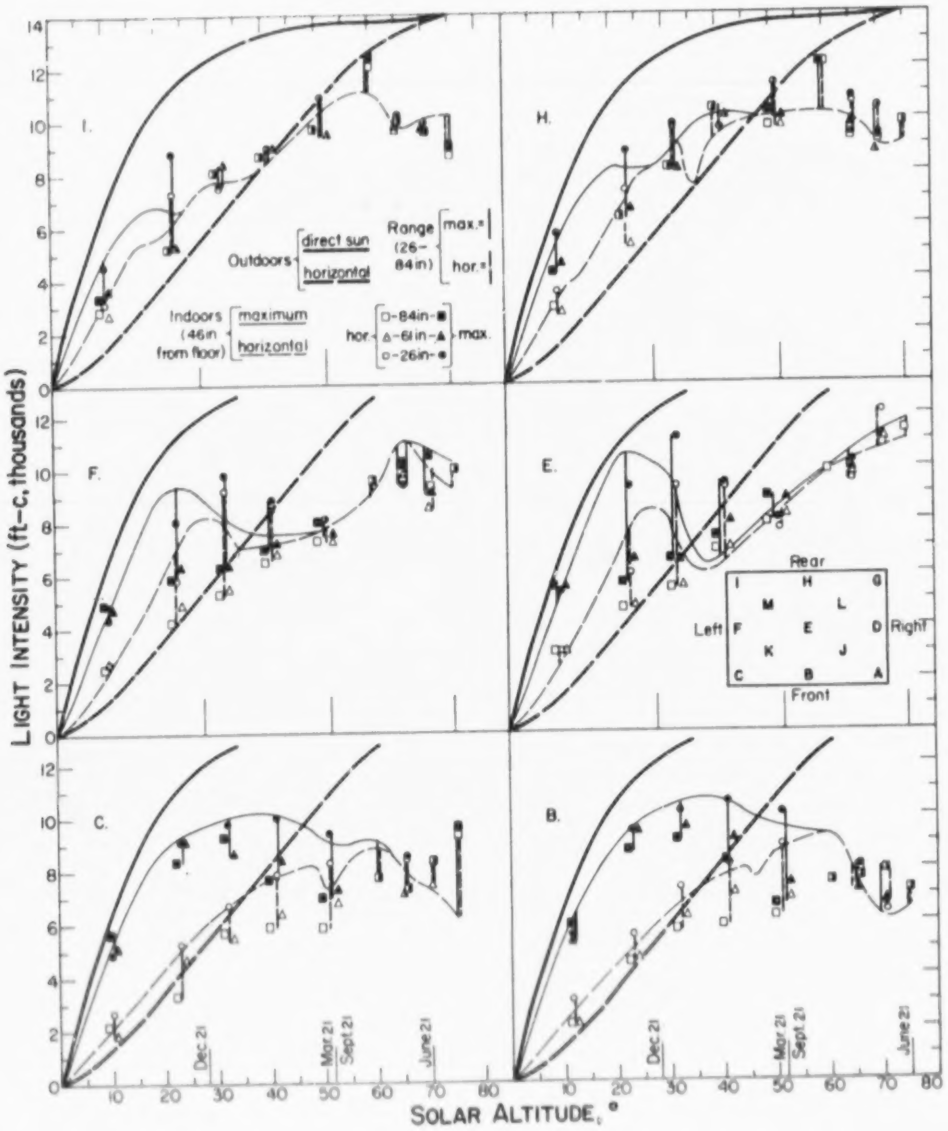


Figure 14

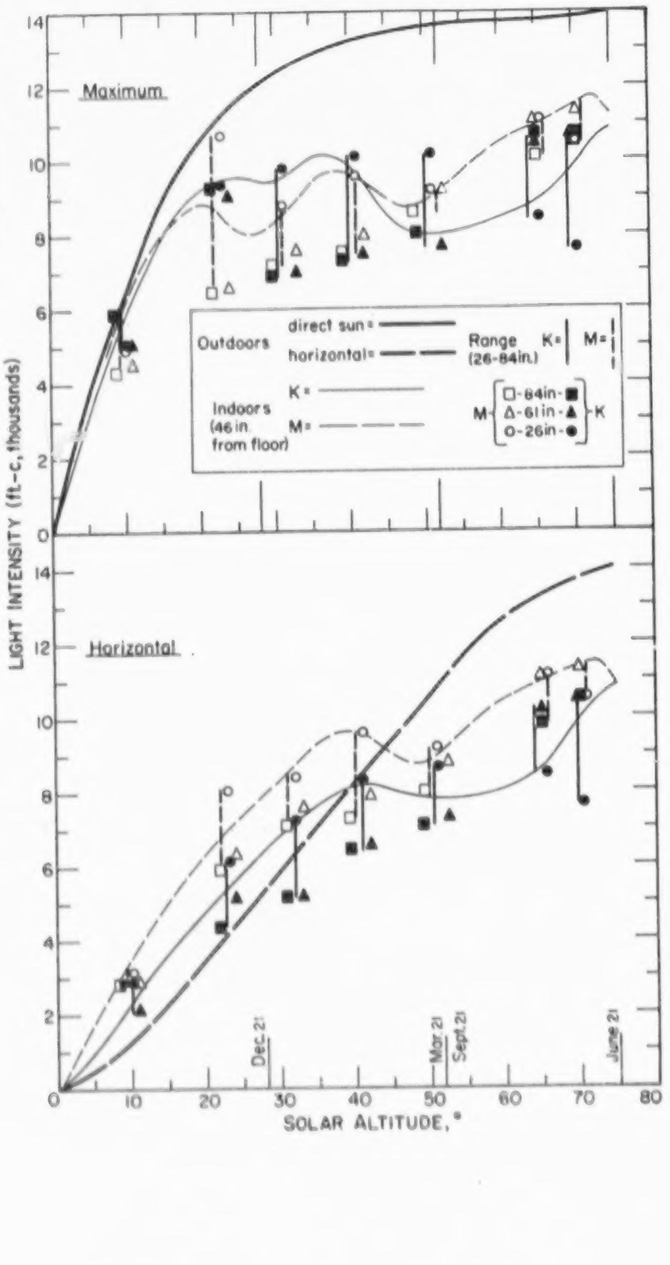


Figure 15

early and late hours of the day. Values rise rapidly to 6-8000 ft.-c and remain high the rest of the day, declining again at the end.

Figure 16 shown below shows intensities at Davis (latitude 38-1/2°) over the day for the four seasons. Note the approximately uniform and equally high intensities during most of the day for all seasons but winter. Table 1 (from Table II of Neubauer et al., 1968), which is shown on the following page, presents sunlight intensity values for the four seasons. Note the high average values over the day and the uniformity of the percentage figures (in comparison to outdoors). The ranges are less that ±17% over the area of the room. A good average duplication of outdoor relationships among seasons is indicated, particularly for maximum intensities. Table 2 (from Table III of Neubauer, et al., 1968) extends data of Table 1 to other heights. The contribution from the windows is noted in the decreasing values with increasing height, particularly above 46 inches. In general, the ranges of irradiancy percentages among the seasons are not great.

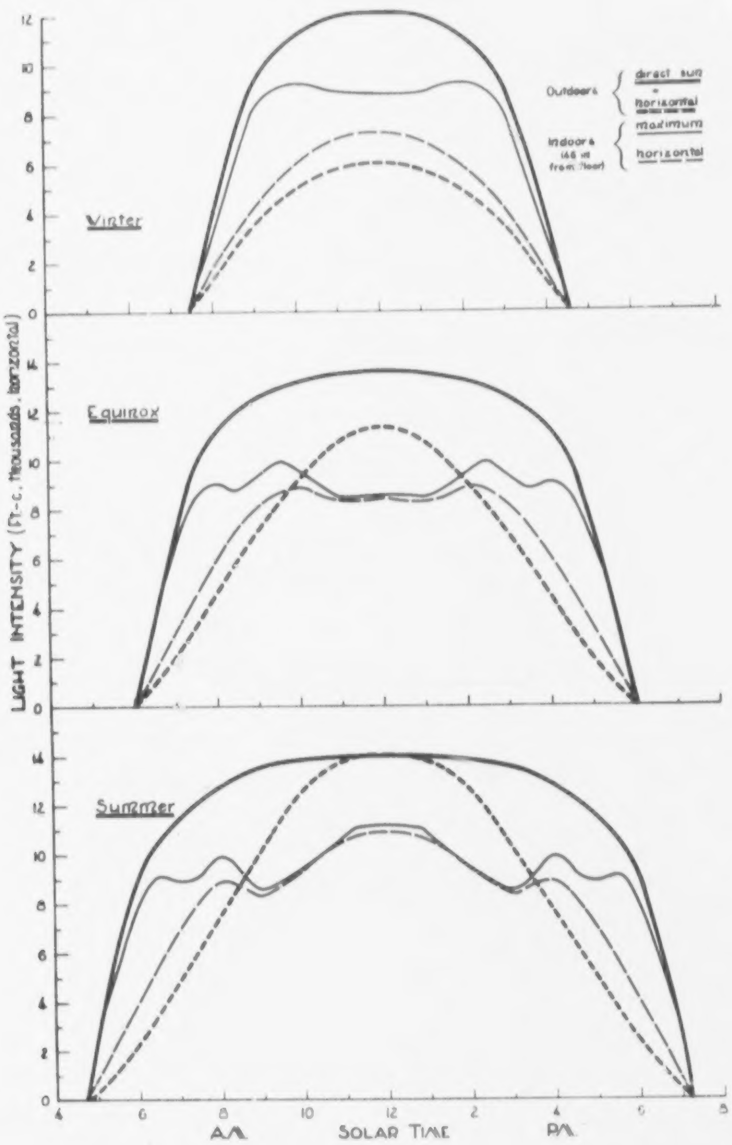


Figure 16

Table 1

Total Daily Sunlight in Rotating Room

Meter Position	Season	Sunlight Energy (x 1000 ft-c[*]hd^{-1})			Overall[‡] Average Intensity Over Day ft-c[*]
		Range Over 13 Positions[†], (±)	Average of Quadrants		
				% of Outdoors	
Horizontal	Summer	13	87.2	92.5	5600
	Equinox	8	62.6	99.1	5040
	Winter	6	34.8	118.8	3720
	Annual Average	--	61.8	98.9	- -
Maximum	Summer	5	102.0	74.8	6510
	Equinox	7	78.0	73.9	6250
	Winter	8	54.5	77.4	5450
	Annual Average	--	78.0	74.8	--

[*] These figures are for true foot-candles, corrected for the 19% difference from measured values caused by omission of the green filter in the illumination meter, as explained earlier (5, 7). The distance from the floor is 46 inches.

[†] These positions are indicated by letters A-M in Fig. 14

[‡] Overall average covers positions A to I in Fig. 14.

Table 2

Total Daily Sunlight at Different Heights in Rotating Room

	Total Light Energy[†], % of Outdoors				
Height[*], Inches	26	46	61	84	103
Horizontal					
Summer	90	87	78	80	80
Equinox	104	96	85	86	78
Winter	123	120	94	92	83
Annual Average[‡]	101	95	84	85	79
Maximum					
Summer	73	70	63	66	--
Equinox	74	71	63	64	--
Winter	74	73	59	57	--
Annual Average	74	71	62	63	--

[*] Height from floor.

[†] Average in position indicated by letter A-M in Fig. 14.

[‡] Annual average covers the four seasons.

Figure 17 shown below illustrates the daily sunlight irradiancies over the year at different heights from the floor. Values do not fluctuate far from the horizontal outdoor value.

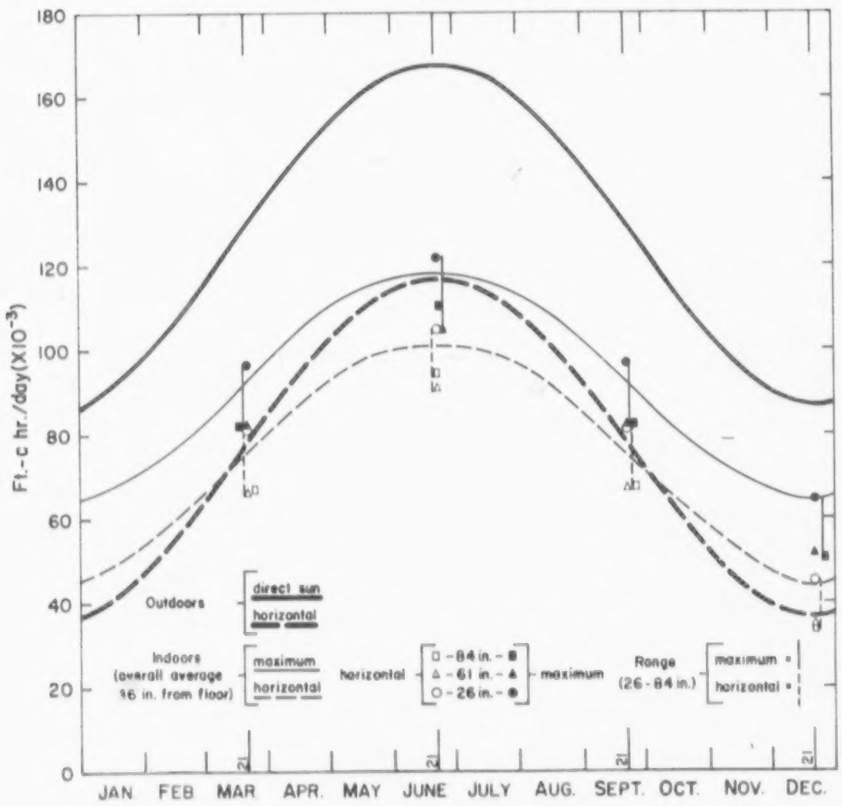


Figure 17

Figure 18, which appears on the following page, shows the progressive increase in daily light units admitted by the series of designs we studied, culminating in the rotating unit. Figure 19 depicts the glowing appearance of this room in the late afternoon of October 5th. Sugar beet plants may be seen behind the windows. The high degree of brightness inside arises in part from the chromium paper-covered rear wall that reflects light admitted from the roof in addition to that admitted by the front windows.

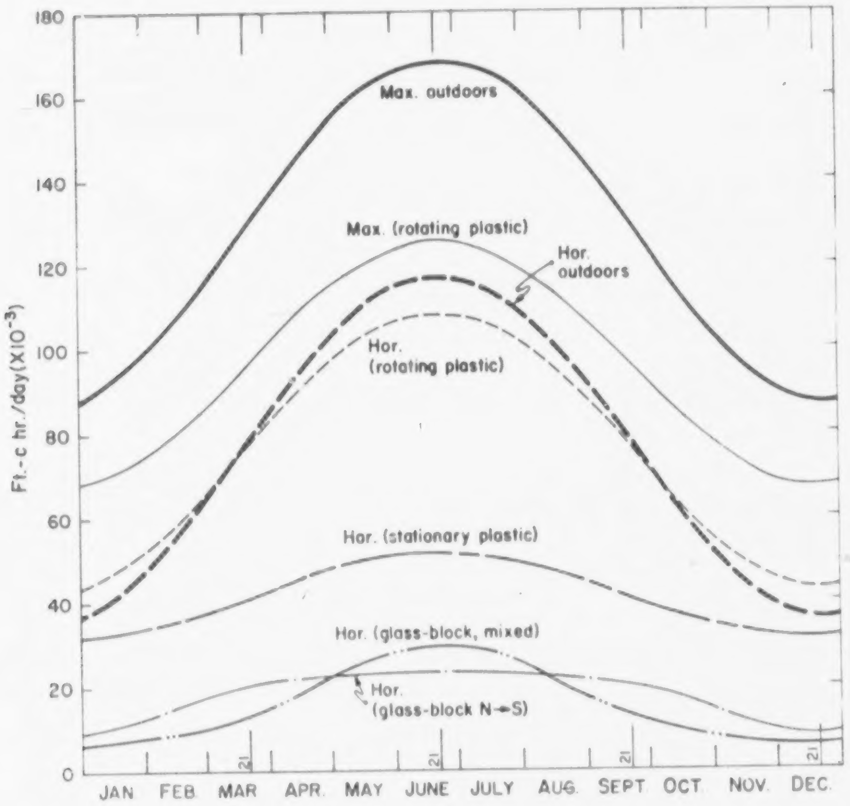
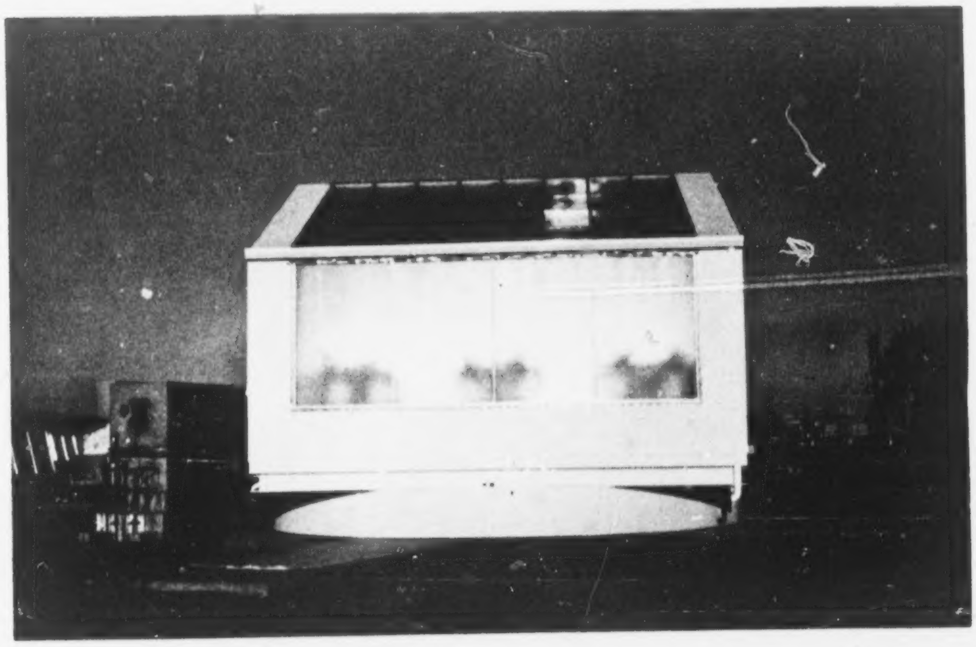


Figure 18

Figure 19



Many species of plants have been grown in these sunlit rooms over the past nine years. In the early model stationary room with the glass-block roof[12] cool-weather plants grew well over a 5-week period (February through March) when sunlight was supplemented by large quantities of incandescent radiation (36, 1500-watt lamps) to give a minimum of 1250 ft-c for 16 hours per day.[13] The air temperature was 60°F by day and 55°F at night. Obviously the air flow was adequate to keep the plant temperature regulated. Plants grown for comparison at the same time in the coolest glasshouse available are on the left, and those in the sunlit room are on the right side for lettuce (See Figure 20 below), pea (See Figure 21 on the following page), spinach (See Figure 22 on the following page), and radish (See Figure 23). Dry

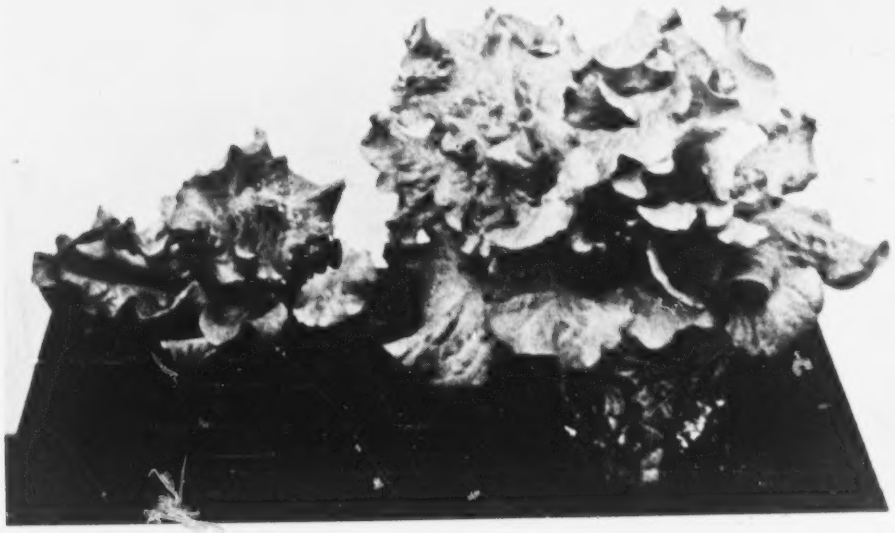


Figure 20

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[12] Zscheile, et al., 1965, op. cit.

[13] Zscheile, F. P., H. R. Drever, and B. R. Houston, 1962, "Light Quality for Plant Growth Excellent in New Phytotron," Calif. Agr., 16 (1), 13-15, January.

Zscheile, F. P., S. M. Henderson, A. S. Leonard, L. W. Neubauer, and I. J. Szluka, 1961. "New Davis Phytotron Follows the Sun," Calif. Agr., 15 (11), 1-3, November.

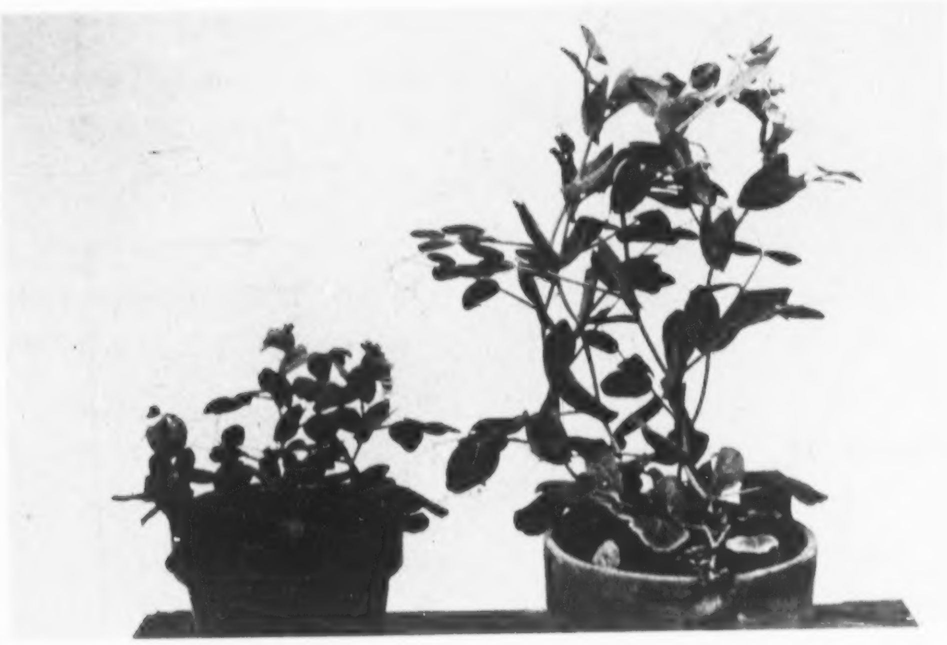


Figure 21

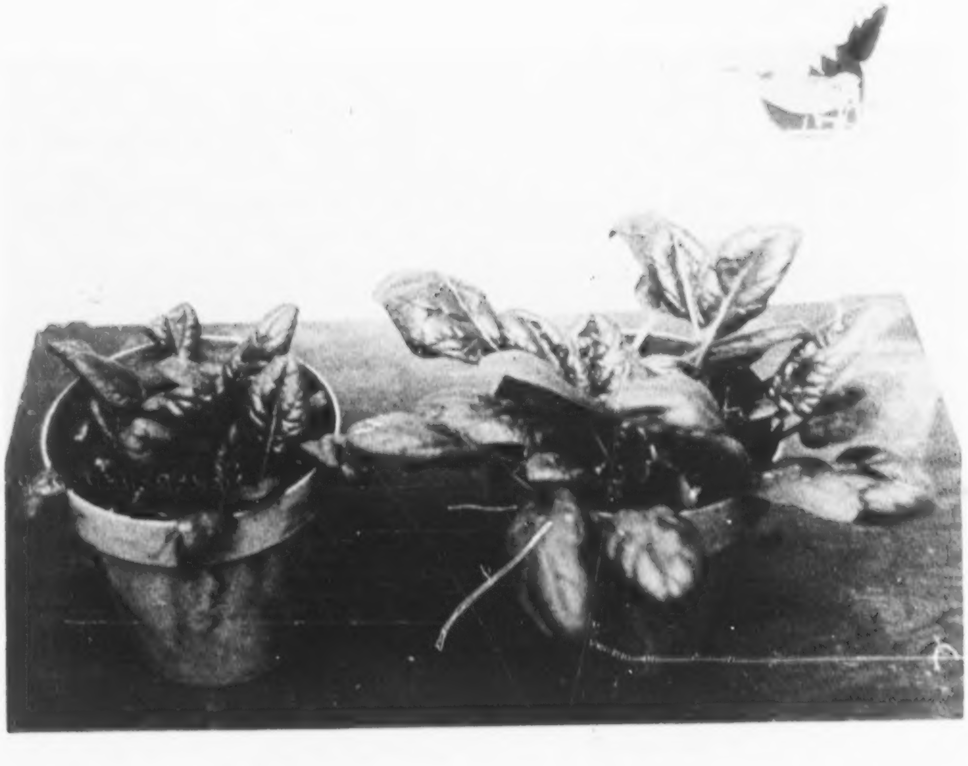


Figure 22

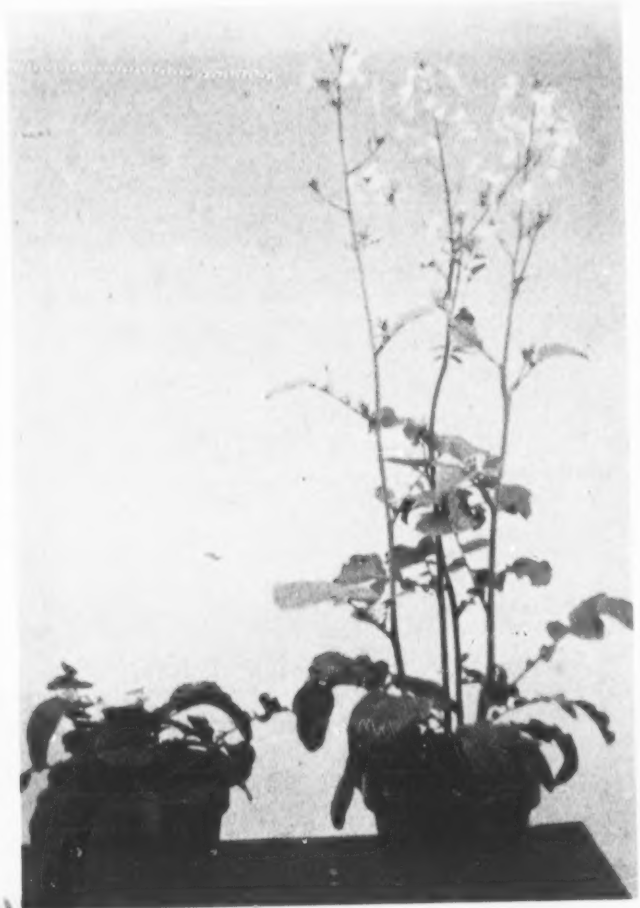
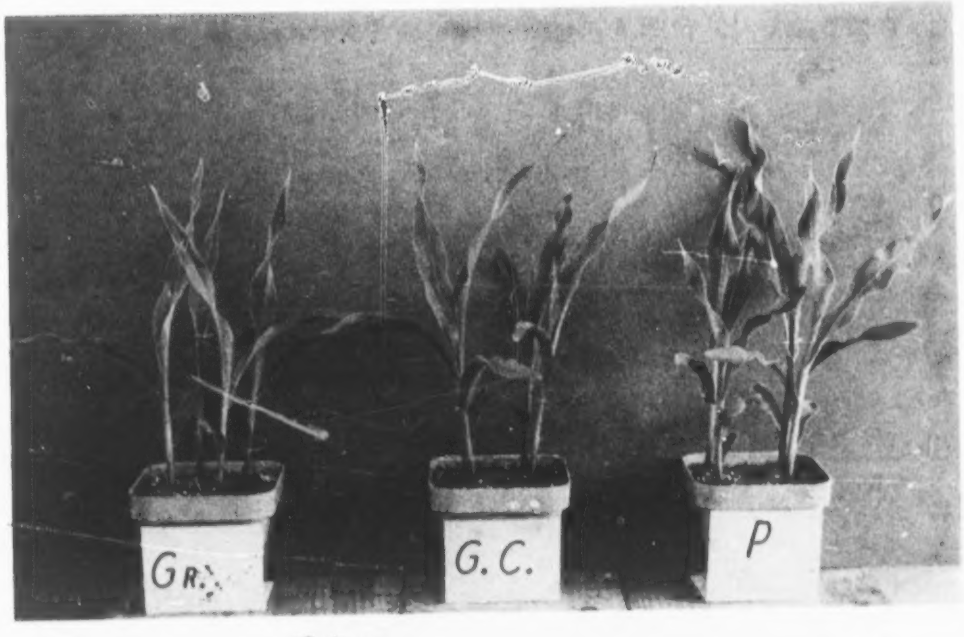


Figure 23

weights were 2.5 to 3.6 times greater in the sunlight room than in the glasshouse. Maize, 14 days after emergence is shown in Figure 24 below. The plants in the center pot were grown in an artificially-lighted growth chamber (800 ft-c, 70°F, 16-hr. day); the sunlit plastic room was kept at 90°F. The sun plants had dry weights 2.25 and 1.8 times those of the glasshouse and growth chamber plants, respectively. Sugar beets were grown in uniformity trials at different locations in all three of our

Figure 24



large model rooms.[14] Variability coefficients were <10% among the various areas of the rooms for dry weight, sugar content, and other measurements on beets at twelve weeks of age.[15] Figure 25 shown below illustrates sugar beets in the stationary room[16] 55 days from planting. Other plants studied were tobacco, wheat, barley, tomato, grape, and trees of pear and olive.

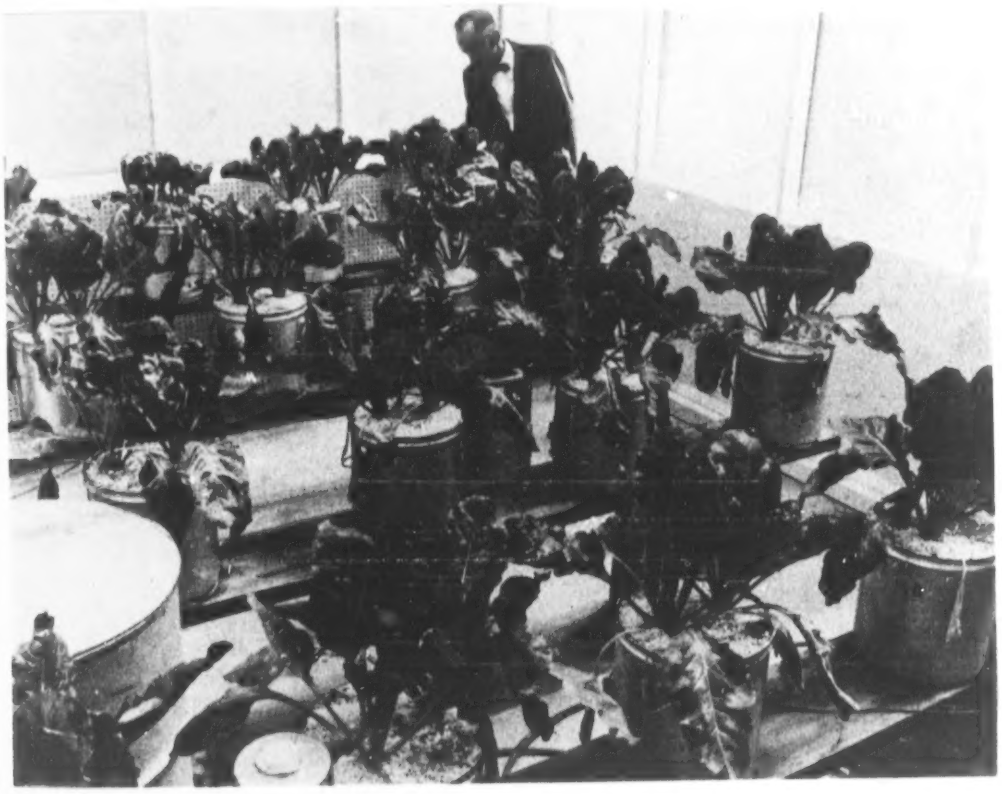


Figure 25

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[14] Zscheile, et al., 1965, op. cit.
Zscheile, et al., 1967, op. cit.
Neubauer, et al., 1968, op. cit.

[15] Zscheile, F. P., Jr., and R. S. Loomis, 1968. "Uniformity of Sugar Beet Growth in Sunlit Phytotron Units," Agri. Meteorology, 5 (5), 361-71, Sept.-Oct.

[16] Zscheile, et al., 1967, op. cit.

In the rotating room additional species, such as sorghum, sunflower, rice, and safflower have also grown well. We are finding these rooms very useful in seeking optimum environmental conditions for crops, in applying stress of temperature, and in imitating climates of areas remote from Davis. Such climates may be reproduced when necessary.

From the standpoint of economics,[17] the initial capital cost per sq. ft. of useful plant space of the rotating unit is about 1/3 that of artificially-lighted chambers. In Davis, which is a sunny location, the operational power was less than 10% of that for artificially-lighted chambers when all were employed in typical experimental studies on plants over a period of a year. Three sets of artificially-lighted growth chambers were studied, located in 1) basement of concrete building, 2) headhouse, and 3) glasshouse. The total power required in sunlit rooms per light unit admitted was often less than 1% of that for light produced in the artificially-lighted chambers. Lamp replacement and labor involved would add 30% to the cost of the latter. The stationary model costs about 1/2 as much as the rotating unit and admits 1/2 as much sunlight averaged over the year.

As to future prospects, many modifications could be made in these rooms to accomodate special problems or requirements:

1. Incandescent light could be focused from outdoors through windows around the edges of the roof to supplement sunlight for lengthening the photo-period or promoting photosynthesis in cloudy weather.
2. Photoperiod could be shortened by a dark curtain to reject sunlight[18] or by putting plants into adjacent darkened areas behind present

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[17] Zscheile, F. P., Jr. 1969. "An Economic Study of Egergy Utilization in Plant Growth Rooms -- Comparison of Sunlit Units With Conventional Types and Glasshouses," *J. Ag. Eng. Res.*, *14* (3), 249-62, July-September.

[18] Zscheile, *et al.*, 1965, *op. cit.*

rear wall.

3. Air composition might be varied as to contents of CO_2 and O_2. Fertilization by CO_2 could promote faster growth and, in some cases, shorten the time needed for experiments. The rooms may be made as tight as desired, so that CO_2 and O_2 contents could be physiological variables; effects of some smog constituents such as CO might also be studied.

4. Root temperatures, which tend to be high in pots standing in the sunlight, could be controlled easily by placing the root containers in a thermo-regulated water bath. Aluminum wraps or white paint are easier methods of reducing radiant heating effects. Native soil in situ might easily be used in the stationary room by simple omission of the floor. Root systems of large plants could then develop in an unrestrained manner.

5. Any degree of cleanliness desired could be imposed upon the building to facilitate quarantine conditions or the study of disease or insect infestations.

6. Humidity control above ambient conditions is simply done by a controlled fog machine as done presently in these rooms to maintain a minimum value of relative humidity; facilities for low humidity could be added if necessary.

7. These rooms should be excellent outer environments for small-scale experiments that might be easily assembled in glass or plastic containers in which very precisely controlled conditions nearly like those of the large room were desired. Such experiments should then require a minimum of additional instrumental equipment of low capacity.

8. By the addition of one slender pillar to support the roof and by minimum strengthening beams in the roof, the area of the stationary

model could easily be increased four-fold by doubling both the length and the width. Suitable air flow modifications could maintain a similar degree of temperature control. Such large rooms would be excellent for the study of large populations of plants.

In conclusion, I point out that the need is urgent for more such rooms so that different crops and different temperatures may be employed simultaneously. Results from such work may then be applied to alleviating food shortages anywhere in the world. Let us learn much more about the physiology of our crop plants, their hereditary potentialities, and how to get the maximum benefit from them. We shall need the best they can produce for an unforseeably long time in the future.

DISCUSSION

QUESTION:

I was wondering if you could experiment with a plastic dome. It seems to me that with a plastic dome you wouldn't have to follow the sunlight; it would cut out all electrical or electronic equipment, and you could grow plants in the ground. Perhaps you could set one room up with a fixed dome and another room without one for comparison.

ZSCHEILE:

Yes. This was considered to some extent. Of course, the Climatron installation in the St. Louis Botanical Gardens, which Dr. Gates is currently directing, is a plastic dome. This is a very large dome. He can tell you much more about it than I can; he has pictures that he can show you. We considered this for experimental purposes. I think that this is not the most favorable condition for our objective because the sunlight at all times will be hitting almost all of the surface at a glancing angle. In the first place if its surface is curved, the sunlight will hit only one spot in a perpendicular manner. Bearing in mind that we wanted the maximum light inside, if over a great deal of the surface the sunlight will be striking at a more or less glancing angle,a great deal would be lost by reflection so that it would never get inside the room. Moreover, this type of construction in a curved fashion is somewhat expensive. I think it would be considerably more expensive than the standard square and flat construction that we use. Some measurements are available on this sort of thing, but it did not appear to be practical to us. I think it's fine as used in St. Louis to house a public demonstration area.

QUESTION:

What can we do about pollenation? Have you done any work on pollenation?

ZSCHEILE:

Not as such. But some of our researchers have studied the formation of pollen as a function of temperature in these rooms, particularly with olives and tomatoes. For instance, Dr. Paul Smith in the Vegetable Crops Department, is doing a very interesting experiment at the present time: He is seeking a tomato variety that will do well in the coastal counties, where the nights are usually cool. Tomatoes like a colder night temperature than the day, but not so cold as in the coastal counties. He has accumulated a wide variety of genetic material. He's growing these and selecting them for three things: pollen formation, fruit set, and seed set. Even though we have pollen formed, it may not set fruit or seed. So he's working out something there and it may prove to offer some interesting results. This general problem could be studied extensively in these rooms, I think.

ENVIRONMENTAL PHYSIOLOGY AND CONTROL IN SPACE

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SUMMARY

Human performance in space is dependent upon the maintenance of an environment which does not produce untoward degrees of stress. Fortunately, most of the physical characteristics of the crew members' environment may be controlled in the spacecraft and space suits at levels compatible with normal physiological function. These levels constitute the ideal physiological design specifications and are briefly described. At certain times during the space missions, the imposition of physical stress may be inevitable as in the sustained acceleration of launch and reentry, or during emergencies. It is therefore necessary to know what is the tolerance of man to differing degrees of gas pressure and composition, heat and cold force fields, and other environmental parameters. Weightlessness is one characteristic of the space environment that is unique, which can produce physical change, but which does not seem to be intolerable. Environmental control systems in space vehicles must be designed for and operated under special circumstances. Recovery of metabolic water and oxygen are necessities for long-duration missions. In the future, it may be desirable to synthesize food in some form of closed ecological systems.

The human physiological system is not able to withstand the extreme environmental conditions of free space. Direct exposure of man to this environment produces loss of consciousness in a few seconds from the absence of oxygen, boiling of the fluids in the body because of the vacuum, extreme heat and cold, and exposure to damaging radiation from the sun and from other sources.

Man must, therefore, be protected when he travels into space. To provide pressure so that body fluid boiling will be prevented, he needs a pressure container -- the space vehicle or space suit. To provide adequate oxygen to maintain life, the pressure of this gas must be kept at a level similar to what we breathe on earth. To keep his body temperature under control, some form of conditioning system must be provided. To keep ionizing radiation down to an acceptable level, the wall of the spacecraft must be sufficiently thick to absorb the high energy particles emitted from the sun during severe solar storms.

The crucial question facing the environmental physiologist is, "Exactly what level should the temperature, pressure, gas composition, and other environmental variables be maintained?" Ideally, the answer is fairly straightforward. It is simply stated as the same environment as the optimum for normal working existence on the surface of the earth. The prescription would then read:

Pressure = 1 atmosphere
Oxygen = 20%
Nitrogen = 80%
Temperature = that required to keep skin at 33°C
Humidity = 10 mm. Hg
Noise - None
Vibration - None
Ionizing Radiation - None
Magnetic Field - Not greater that 0.3 gauss
Contaminants in the Atmosphere - None

Added to this simple formula would be the needs for a balanced, wholesome diet, a water supply of about 3 liters per day, and an effective way of removing waste products.

Unfortunately, the real situation is very complicated. The main reason for this complication is that the simple requirements are impossible to meet. Not only is this the case for man in the space environment, but it is also true here on earth. For example, our own atmospheric pressure is not constant, but varies from day to day at any one point, and varies even more with altitude. None of us lives under conditions of constant temperature and humidity. Noise and vibration are an almost inevitable accompaniment of everyday life. We are all subjected to small amounts of ionizing radiation, and we are always inhaling many contaminants in the air we breathe, as those who live in smog areas know only too well.

Perhaps, then, the requirement for maintenance of life in the space vehicle should specify not an ideal environment, but one similar to that actually experienced by people on the earth. The problem here is that there is always a wide variety of environments on the surface of the earth so that it is not possible to pick any one.

Since it is not possible to provide an ideal environment, the aim should be to provide one which will be as safe as possible and allow the crew members of the space vehicle to carry out their tasks without any significant decrease in efficiency. This means that an attempt must be made to describe the limits of temperature, humidity, pressure, radiation, and other variables within which a high level of safety and performance may be assured.

In the case of pressure, there are no known serious effects of a reduction level from one atmosphere to half an atmosphere or less, provided oxygen pressure is maintained. This means that the space vehicles or spacesuit do not have to be pressurized to one atmosphere, and that nitrogen may be removed without fear of upsetting physiological mechanisms in any significant way. The question then becomes, "How much nitrogen may be removed?" This is difficult to answer on an adequate statistical basis because of the lack of previous knowledge or experience. For example, no one has lived for, say even six months, in an atmosphere without nitrogen. One of the tasks of the environmental physiologist is now to experiment to discover what levels of nitrogen, if any, are required and for how long a period of time the change may be tolerated. In environmental chambers, subjects have lived for periods of a month or longer without any significant amount of nitrogen present with only minor problems.

In the case of temperature, the ideal is, perhaps, a "comfortable" condition. The problem now becomes one of translating "comfort" into some form of enigneering specification which will enable the spacecraft and spacesuit designer to construct the environmental control system. The magnitude of the problem can be realized when it is understood that the thermal condition of the human subject is dependent on air temperature, wall temperature, emissivities and reflectivities, humidity, air movement, clothing characteristics, air density, air composition, metabolic rate, acclimatization, and a number of other physiological factors. Many years of physiological experimentation have, in this case, given us a good understanding of the mathemetical, physical, and physiological ways in which these factors combine to influence the temperature of man. Temperature control systems are, therefore, a little easier to describe requirements for than some of the other environmental parameters. The systems in use in spacecraft and spacesuits of today are coming closer to giving something like an optimum design state for thermal comfort in the crew members.

Regarding noise and vibration, the environmental limits are also fairly well understood, although many years of physiological experiments are required before a comprehensive picture of human response and tolerance are built up.

Ionizing radiation in the space environment could cause tissue damage to the crew of space vehicles if there was not a sufficient amount of mass in the vehicle wall to stop a high percentage of the high energy particles, protons and helium nuclei which stream out from the sun in large numbers during solar flares. In the case of the Apollo vehicle, the wall is sufficiently thick to give this protection.

The case of contaminants in the cabin air is difficult when it is necessary to specify the upper tolerance limits for the many thousands of different possible contaminants. In the space vehicle it is, however, easier than in the terrestrial environment, since the small size of the space vehicle obviously cannot give rise to as many different kinds of chemical contaminants as are found on earth. Establishing toxic limits for these compounds is a very complex and time consuming process, particularly when long duration exposure is involved. This is equally true in the space and terrestrial environments.

In summary, while the specification of environmental control systems to meet the needs of man in the space environment might appear to be simple, it is, in fact, as complex a task as that of specifying the tolerance limits of exposure to stress that occurs in the terrestrial environment.

DISCUSSION

QUESTION:

Wouldn't it have been wiser and more efficient to take the plans and effort expended on space research and use them for solving some problems here on earth rather than hoping for some sort of "spinoff" from the problems in space aiding in solving the problems on earth?

BILLINGHAM:

I don't know; I don't think anyone knows. But, I don't really think so. I think that one of the most important thing is to keep in the forefront on science and technology; there have been countless examples where nations and parts of nations which have kept in the forefront on science and technology have ultimately discovered and developed new techniques and new ways of tackling problems that existed before. What I'm saying is, let's have some programs which advance our science and technology to new heights because, in the long run, they are going to produce the most tremendous general diffusion of that knowledge and those techniques throughout the entire world.

QUESTION:

You said earlier that one of the optimum circumstances of the spacecraft is that there would be no pollutants in the air that the spacemen breathe. Suppose you have a spaceship going into outer space and all of a sudden, the air coming out of the tanks was coming out equal to that in Los Angeles on an average smoggy day. This would be considered some sort of an emergency, wouldn't it? Ranging the emergencies on a scale from one to ten, how would you rate this?

BILLINGHAM:

It would depend upon the phase of the mission; but, probably somewhere half way between the two. The reason, though, is this: If that happened, it would mean that something had failed and any failure in the spacecraft, obviously, means that you have to do something. You have to introduce a new circuit; you have to take out a filter; or put in a new one; or you may have to decompress the spacecraft or something like that.

QUESTION:

But, say this is the air you had all the way. There is no chance of correcting it. Would you recognize this as a potential hazard to the crew?

BILLINGHAM:

Yes, but it would be a very small one; extremely small. The possibility that it would cause any serious damage is slight. It would be annoying, perhaps something like streaming of the eyes when one is trying to perform some critical maneuver, or something like that. And that certainly is a possibility. It would not be a hazard in the same sense, I think, as it is for the Los Angeles community because it occurs for a very short time. There's another reason why it's so difficult to pin down these numbers for terrestrial environments when you're dealing with odd times of exposure. We can find out fairly easily what toxic levels are for seven-day exposures, particularly when there's a limited number of things in the spacecraft which give off toxicants. But, when you deal with a lifetime and an almost infinite number of chemicals, the problem is extremely complex.

CULTURE AND SUBCULTURE AS ENVIRONMENT

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SUMMARY

As we relentlessly yet abrasively move into the final third of the Twentieth Century, it becomes more apparent that any discussion of "Man and His Environment" purporting to be both comprehensive and scientific cannot be restricted to the purely physicalistic features of the man-environment relationship. A reductionist account of man-in-nature necessarily omits genotypic attributes of human nature. The social science construct "culture" is fundamental to a consideration of these elusive, but crucial, symbolic properties of the figure-ground matrix sustaining all mutually acknowledged members of the human species. An explication of the culture and subsequent application of this and related terms in an analysis of Twentieth Century America suggests several unorthodox perspectives for confronting current environmental predicaments. The resulting treatment of this social phenomena of culture, subculture, and contraculture as symbolic environments of varying compatibility with the physical environment has implications for concerns about the spectre of mass man in mass society as well as the technological erosion of human liberty.

A juxtaposition of the terms "culture" and "environment" generates a fundamental paradox. Like the dilemma of life and death, it presents us with a situation from which we may never recover --- history, the nightmare from which we are trying to awaken. Hope diminishes as a function of our delay in grappling with it. The paradox is this: In terms of human existence, culture and environment are either synonymous or else one must subsume the other.

"You just don't know what lonely is 'till you get to calling hogs."[1]

We tend to take the world as given. But, we rarely think of ourselves as gifted in this sense. Under most circumstances we tend to assume that things are pretty much what they seem. This is unfortunate because right now things don't seem so good. In the words of Frank Zappa, "All your children are poor unfortunate victims of systems beyond their control."[2] And maybe it's not limited to children.

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[1] Traditional American Ballad.

The Earth --- that's the principal empirical referent for the world we take as given (or at least, it should be) --- is getting crowded, messy, and dangerous; in a word, bothersome. Do we really believe that? I wonder . . . How do we really know that this is what's really happening? Well, a lot of people are saying it, and why would they lie? Why, indeed? Why not?

What is hard to believe is that anybody really believes we are making Earth unfit for children. If they did, surely they would do something about it. Perhaps they don't believe there is anything they can do about it. Maybe they're just busy doing something else. It must be something unrelated to living on Earth. That's it! They're doing their thing and it's unrelated to living on Earth. And we call that reality!

Actually, there are many realities, multiple realities.[3] Among these realities, there is one that is usually more important than the others. It is more important because we share it with other people. Let's call it the world of everyday life. Even more than the others, we tend to take it as given. Yet, the world of everyday life was not, in a strict sense, given. We constructed it, but not on our own. We had help. So much so that sociologists who take delight in building other realities by talking about the important one, describe this group effort as the "social construction of reality."[4]

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[2] "What's the Ugliest Part of Your Body?" Song from the album "We're Only in it for the Money," The Mothers of Invention, Lyrics by Frank Zappa, Bizarre-Verve Recording No. V/Vg 5045X.

[3] Alfred Schutz, "On Multiple Realities," Philosophy and Phenomenological Research, V, June, 1945, pp. 533-576.

[4] Peter L. Berger and Thomas Luckmann, Social Construction of Reality, Anchor Books: Doubleday & Company, Inc., Garden City, New York, 1967, 219 pp.

The blueprint or plans for the construction job is sometimes referred to as "culture". It consists of general ideas about the way the world is and the way it should be. These are handed down from generation to generation by groups of people gathered together in what sociologists call institutions. Sociologists like to give big names to things that already have shorter names, like family, school, church, business, government. But, that's their bit; it's part of their "subculture". Because these plans get passed around a lot, they get kind of messed. Fortunately, most people are very understanding and don't complain and use 'em anyway. You see, they don't get revised very often. They usually go pretty far back and I'm not even sure what they're based upon. So, it's lucky that some people are nice and just make do the best they can. I've heard of people who have gotten them revised or even made up new ones, but it's a lot of work and the people who have time to waste on that sort of thing are pretty weird. Besides, it's sort of in to have a fairly old copy --- like antiques. There are still a lot of these plans around that show the Earth in the center of the Universe, you know, with everything revolving around it. Actually, the ones I've seen don't really show the Earth; it's just a map of the United States with a circle around it. Very quaint.

Mostly, however, culture plans tell you what you can expect in various situations and how to stay out of trouble. You can use them for a lot of different scenes and they keep people from getting up-tight in new situations or when something unexpected happens. Almost all of us use the one called American culture. It's not very complicated and it's worked pretty well so far. It's even earned the nickname "conventional wisdom".

> We're talking -- about the space
> between us all
> And the people -- who hide themselves
> behind a wall of illusion

These are the words of George Harrison.

By conventional wisdom, a man who unknowingly contaminates his living space is a fool. If, in doing so, he also contaminates the living space of others, he is a menace. Were he to do these things knowingly, we would judge him as mad or demonic. But, what if he enlists the aid of others in his demonic project, organizing their efforts according to the highest principles of rationality and efficiency; and then, somehow, even gaining your cooperation in these efforts, achieves these ends so effectively that contamination of the environment is no longer dependent upon his existence or, for that matter, the presence of any specific individual? Conventional wisdom proves inadequate to provide an appropriate designation for such an occurrence. Further painful reflection suggests, however, that it would be difficult to find a better label to describe these processes than the designation Twentieth Century American Culture.

All things considered, we usually get what we deserve.

The concept of environmental pollution describes the consequences of such machinations, i.e., the "what" of what has occurred. In order to describe the process, i.e., to understand the "why" and "how" of what has happened, it may be necessary to invoke the concept of cultural pollution.

For several years now, I have wished that some young lady would crochet and present me with a sampler having the inscription:

MY HOME IS MY CASTLE
F. Kafka

Any discussion of "Man and His Environment" that is restricted to the purely physicalistic aspects of the man-environment relationship will not only fail to comprehend the total problems of pollution; it will contribute to its continuation. Considerations of a concept of cultural pollution establish a frame of reference for supplementing the necessarily inadequate reductionist account of man-in-nature. Thus, it potentially frees man to redirect the search for the source of contamination within the epistemology of the culture.

"Inasmuch as the struggle for truth 'saves' reality from destruction, truth commits and engages human existence. It is essentially the human project. If man has learned to see and know what really IS, he will act in accordance with the truth. Epistemology is itself ethics, and ethics is epistemology."[5] Lenny Bruce and Herbert Marcuse reach agreement on the moral postulate of social phenomenology -- the truth is WHAT IS.

Recent historical events such as the systematic destruction of eight million persons in the Nazi death camps, Hiroshima, Vietnam, and the activities in Berkeley during the past week[6] offer ample evidence that the fool, the madman, and the devil are still effective agents of our cultural pollution. Our increasingly efficient, but futile, attempts to externalize these "ghosts" create further environnmental evidence of their continuing influence. These all too real representatives of the dark side of human heritage will not be found "out there." The strong conviction that it is only natural to seek the source of our contamination in external reality (in nature) is another element in cultural pollution. This "natural" tendency to perceive ourselves as separate from (with the attendant implication, over) nature is cited by Herbert Marcuse as one manifestation of the false consciousness perpetuated by cultural values that are determined by technological rationality and its inherent logic of domination.

> . . . it is natural only to a mode of thought and behavior which is unwilling and perhaps incapable of comprehending what is happening and why it is happening, a mode of thought and behavior which is immune against other than the established rationality. The degree to which they correspond to the given reality, thought and behavior express a false consciousness, responding and contributing to a false order of fact. And this false

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[5] Herbert Marcuse, One Dimensional Man, Beacon Press: Boston, 1964, p. 125.

[6] The period from May 13-20, 1969, marks the principal events of the "People's Park Controversy" in Berkeley, California. On May 20, tear gas was dropped over most of the U.C. campus by a U.S. Army helicopter.

> consciousness has become embodied in the prevailing technical aparatus which in turn reproduces it.
>
> We live and die rationally and productively. We know that destruction is the price of progress as death is the price of life, that renunciation and toil are the prerequisites for gratification and joy, that business must go on, and that the alternatives are Utopian. This ideology belongs to the established societal aparatus; it is a requisite for its continuous functioning and part of its rationality.
>
> However, the aparatus defeats its own purpose if its purpose is to create a humane existence on the basis of a humanized nature. And if this is not its purpose, its rationality is even more suspect.[7]

The young (along with Professor Marcuse) seem to be saying that the "is" is not what "ought to be". The old are saying that the "ought to be" is what "is". No wonder they can't get it together.

Still, there may be hope. It is helpful to remember Joel Fort's definition of the optimist and the pessimist. If the optimist is one who thinks this is the best of all possible worlds, then the pessimist must be someone who thinks the optimist is right.

I am reminded also of the apocryphal, but contemporary, tale about the group of experts who consulted a computer concerning the best means of reducing automobile accidents. After feeding in all the pertinent data that the experts could think of and after giving the computer a few seconds to digest this data, they then inquired of the computer as to the best way of reducing, or even eliminating, traffic accidents. The computer's answer was as short as it was quick --- "Do away with automobiles." The experts praised the logic of this answer, but with regret informed the computer that this particular answer was unacceptable. They asked the computer to try again. Undaunted, the computer rose to the occasion and, after thinking a few more milliseconds, produced another answer -- "Do away with people."

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[7] Herbert Marcuse, op. cit., pp. 145-46.

The purpose of this rational-technological system that has increasingly come to dominate contemporary cultural forms is defined not in humanitarian terms, but rather, according to the internal rhetoric of the systems themselves. The scientific goals of prediction and control serve the more general purpose of the domination of nature. The very process and increased effectiveness of this effort (technological progress) encourages the extension of these principles to man and his social institutions. The scientific method provides the rationale for the evermore effective domination of man by man. The person is reified and, like the rest of nature, comes to be organized as things and instrumentalities. Operationalism and behaviorism reduce the qualitative features of human existence to quantities, sets of operations, and so much observable behavior.

Just as the increased environmental pollution demonstrates a disregard for the quality of organic life, emphasizing instead the immediate effectiveness of the non-organic and mechanical systems, the contamination effect of the rational-technological imperative on human culture is to reduce its variety and richness of texture. Thought and activity are restricted and ritualized in accord with system requirements. The good life comes to be defined as the total coordination of the individual with society. Marcuse offers a description of the inevitable results of such cultural pollution as the one-dimensional man in the one-dimensional society.

> Thus emerges a pattern of one-dimensional thought and behavior in which ideas, aspirations, and objectives that, by their content, transcend the established universe of discourse and action are either repelled or reduced to terms of this universe. They are redefined by the rationality of the given system and of its quantitative extension.[8]

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[8] *Ibid.*, p. 12.

The essential character of this cultural pollution which I have been describing may be recognized as the trend toward a permanent subjugation of human variety and individual liberty in the service of a quasi-benovolent totalitarian social order. Personal desire and thoughts are systematically transformed to meet the social system requirements.

If the blueprint of American culture gets any messier, it certainly will simplify things. At Columbia University on May 31, 1960, Norman O. Brown began the Phi Beta Kappa Oration with the following remarks:

> I didn't know whether I should appear before you -- there is a time to show and a time to hide; there is a time to speak and also a time to be silent. What time is it? It is fifteen years since H. G. Wells said Mind was at the End of its Tether -- a frightful queerness come into life: There is no way out or around or through, he said; it is the end. It is because I think mind is at the end of its tether that I would be silent. It is because I think there is a way out -- a way down and out -- that I will speak.
>
> Mind at the end of its tether; I can guess what some of you are thinking -- his mind is at the end of its tether -- and this could be. It scares me, but it deters me not. The alternative to mind is certainly madness. Our greatest blessings, says Socrates in the Phaedrus, come to us by way of madness -- provided, he adds, that the madness comes from the god. Our real choice is between holy and unholy madness: open your eyes and look around you -- madness is in the saddle anyhow. Freud is the measure of our unholy madness, as Nietzsche is the prophet of the holy madness of Dionysus, the mad truth.[9]

To this, I can only add that now in 1969, the world, too, is at the end of its tether.

Science owes its existence to man's desire to reduce confusion ---- to bring order out of chaos. And yet the very success within American culture and the advanced technology resulting from our successful scientific mastery of the physcial environment has given rise to new sources of confusion. Michael Harrington is right. This is the accidental century. Much to our consternation, the environment made by man has turned out to be more puzzling than nature.[10]

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[9] Norman O. Brown, "Apocalypse: The Place of Mystery in the Life of the Mind," Phi Beta Kappa Oration, Columbia University, May 31, 1960, reprinted in Harper's Magazine, May, 1961, pp. 46-49.

While reflecting upon the fact that I was to be the only social scientist participating in this conference, I recalled a narrative poem by Baudelaire which reflects the image of a poor waif staring through the window of an elegant cafe as the poet and his friends enjoyed an abundant Parisian supper. Near the end of the poem Baudelaire records that the wistful eyes of the urchin seemed to be trying to communicate a message. "True enough, I subvocalized, as my thoughts focused back on the conference,"I am trying to tell you that the food is poisoned."

The final justification for separate academic disciplines of the human species may be found in human differences. The continued presence of the human species on this planet may be traced to our similarities. Most of my remarks this evening are devoted to the task of encouraging such differences as the principal hope for giving further continuity to the similarities, but then T. S. Eliot expressed this thought far better when he observed, "All cases are unique, but many are similar."

In view of the unsympathetic evaluation of the scientific enterprise as enacted in American culture, I feel that I should comment on my view of the social sciences. The proper function of the social science is to clarify, enrich, and question the image of man; in the words of John Dewey, " to foster . . . a wisdom which would influence the conduct of life." The behaviorist and positivist version of a science of man with its ultimate goals of explanation, prediction, and control necessarily imply domination.

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[10] Michael Harrington, The Accidental Century, Penguin Books, Inc.: Baltimore, Maryland, 1966, p. 41.

If there is any useful distinction to be made between the social scientist's concept of society and the concept of culture, it is to the effect that a culture always has a history. Among other things, this suggests that someone made the culture and, therefore, someone can unmake it; not by the suppression of history, a denial of the past, but rather by trying to comprehend our society in its historical totality.

For us, the sum total of quantitative changes in our world has resulted in qualitative changes in our culture. We have moved from an individualistic, agricultural society characterized by warm, informal human relations to a collective, industrial and urban society characterized by unfeeling, formal social relations. A man's worth is no longer measured by his ability to grow food and craft simple tools with his hands, but rather by his skill in manipulating complex machines, abstract symbols, and other people.

The concept of society usually implies a structural view of a social collectivity taken at one point in time. It is, however, not possible to talk about or view a culture without employing a time dimension as part of the subject matter. Culture, then, consists of the relationship between a social collectivity and its environment looked at over a period of time. In the case of western industrialized society, we have exerted such a high degree of control over our environment that we no longer think about what happened to the Indians.

"In 1964, ten men could produce as many automobile blocks as 400 men in 1954; two workers could make 1000 radios a day, a job that required 200 a few years before. Fourteen operators were tending the glass blowing machines that manufactured 90% of all the light bulbs in the United States. During the 1950's, Bell Telephone increased its volume by 50% and its work force by only 10%;"[11] more work, less labor!

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[11] _Ibid._, pp. 245-246.

Bertrand Russell designates two kinds of work: first, Type I, altering the position of matter at or near the earth's surface relative to other such matter; and, secondly (Type II), telling other people to do so. Type I work is usually unpleasant and ill-paid; Type II tends to be more pleasant and better paid.[12] I believe that most of us present have the good fortune to be engaged in the latter kind of work. It is, in fact, accurate to observe that an increasing proportion of our society's work force is occupied with Type II, rather than Type I work (except, of course, under the label of hobbies or other kinds of leisure). Thus, it is, indeed, convenient that Type II work is, in principle, capable of indefinite extension; there are not only those who "tell others to do so," but also those who give advice as to what orders should be given and/or the best way to give orders. Mr. Russell's account of the nature of work continues to describe politics as the situation that finds two opposite kinds of advice given simultaneously by two organized bodies of men.[13] The basic skill required for this kind of work is, apparently, persuasive ability rather than knowledge about the subject for which advice is given.

Social change has brought more than ever of Type I work, but fewer people need to be told to do it. Yet, somehow, more people than ever before are still busy with work of the second nature. This does not seem quite right, and we might ask why it is so. While I cannot claim to know the best answer, it is becoming increasingly obvious that if we continue to avoid trying to answer this question for ourselves we may lose the right or the ability to know why we do anything.

Somehow, just when our efforts have created a technology capable of giving us anything that we decide we want or need, at the same point in history when this heretofore Utopian dream of unlimited potential is becoming a reality, the majority of us seem to have lost our ability to make decisions. In the face of unlimited freedom, we depend upon someone or something else to decide what we want and why. The cruel irony of this latest development in the human predicament is well expressed by Erich Fromm's description of "the escape from freedom."

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[12] Bertrand Russell, "In Praise of Idleness," in Social Humanism, Erich Fromm, (Ed.) Anchor Books: Garden City, New York, 1966, pp. 246-259.

[13] Ibid., p. 248.

But, surely, you might rightfully inquire, this is an exaggerated description of the situation? Since work --- work of both types --- is obviously getting done (the evidence is all around us) and decisions are obviously being made, many of us have not lost the ability to make decisions. Undeniably true, but under what conditions do our decision-makers operate? What kind of assumptions provide the basis for these decisions? And of equal importance, what is the quality of the information guiding the decision-making process?

It is quite possible that the conditions, assumptions, and information employed by our current decision-makers are adequate for handling structured problems; by this, I mean problems for which the decision making rules can be set out in advance. I am in no way convinced, however, because I have yet to see any evidence, that our decision-makers and the policies and strategies they rely upon are capable of meeting the challenge of unstructured problems, the problems we have never faced before because they did not exist until now. These are the tactical problems created by change and they are, of course, the crucial problems of our age. There is little consolation in the fact that our decision-makers can handle old problems with greater efficiency and effectiveness. If we could tolerate the shame and loss of authority implied in putting all such problems into the hands of computers instead of only some men, we could raise efficiency to its optimum limit. This would force the decision-makers to confront the dilemmas of change problems for which the total range of possible solutions is yet to be imagined. A logic machine is of less help here, presented with a set of stupid alternatives, a computer can only give back a stupid answer --- "Do away with people."

Unfortunately, decision-makers must face their toughest tasks without being able to count on the binary circuits we have so quickly come to depend upon. Further, despite the fact that the promise of achieving anything we decide is desirable, our decision-makers are constrained from employing the full potential of their human creative ability to conceive of new solutions for new problems. They are constrained by the continuing influence of old decisions and by our total commitment to the desirability and infallibility of our technology. For some unfathomable reason, we tolerate these restraints even though we know, at some level of consciousness, that the old decisions were arrived at in a world very unlike the one in which we now live --- a world in which we daily curse those features of the technology that give us more pain than pleasure.

In an attempt to deny the discrepancy between our actions and our doubts about the wisdom of accepting the old decisions and all technology as a supreme, unalterable good, we find it necessary to rationalize that what has been necessary is now being desirable. Despite the incessant repetition of this rationalization, it is never quite believed, though the disbelief is often reduced to a vague sense of distrust and suspicion. The widening "generation gap" may be traced to the increased awareness on the part of many of the young that our actions bear little relation to our professed goals and purposes. Youth seems much more sensitive to pollution, both environmental and cultural. If there is any validity to this critical analysis of the state of the current of decision-making in our society, then we must admit that, as a culture, we are in real trouble. American society is being seriously threatened by our own inability to be honest, responsible, and unselfish with respect to the global environment we live in as well as other persons and life forms that share the planet.

Several of the previous speakers at this conference have referred to the talk delivered by Nobel Laureate George Wald. This address, entitled "A

Generation in Search of a Future," was at least as relevant to the subject of cultural pollution as to the topic on environmental pollution. Dr. Wald's observation that " . . . our national symbols have gone sour"[14] certainly seems to have more to do with our psyches than our somata. I am pleased that such a distinguished member of the scientific community has spoken so forthrightly. I hope that more will find courage to follow this example. On May 16, Dr. Wald spoke again, this time at Grace Cathedral in San Francisco under the heading "Therefore Choose Life." Among other notable comments he fielded the question as to whether he had a plan for "bringing our boys home from Vietnam." He answered briefly and affirmatively, "In ships!"[15]

Where (or, perhaps, when) does the environment leave off and culture begin? For many this will be a meaningless question, not because of any ambiguity of the terms, but rather because of the implied continuium. Thus, in some sense, environment and culture are identical, as when Marshall McLuhan asserts that "our proliferating technologies have created a whole series of new environments."[16] In contrast, the two terms can refer to two very different ways of view as in the case when one speaks of a juvenile delinquent or a Trobriand Islander as products of environment.

A few persons may judge the question "where does environment leave off and culture begin?" as worthy of an answer; though I suspect that the proffered answers would reflect more conflict than consensus. Both anthropologists and paleontologists might reply, "At the dawn of man;" the philologist could join the classicist in proclaiming ancient Greece as the "where" while specifying the "when" in terms of the differentiation of the concept of physis (the WAY of growth, subsequently mistranslated by the Romans as "Nature") into the dualism of "is" and "ought" epitomized in the Platonic

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[14] George Wald, "A Generation in Search of A Future," reprinted in the KPFA Folio, May, 1969, Vol. 20, No. 5, Pacifica Foundation.

[15] George Wald, "Therefore Choose Life," radio broadcast, May 16, 1969, KPFA Pacifica Foundation.

[16] Marshall McLuhan, Understanding Media: The Extension of Man, McGraw-Hill Book Company: New York, 1965, p. viii.

"appearance" and "essence" which is best known to us in the guise of subject and object, the inner and outer reality. Moving on to other categories, for the Judaic-Christian theologian, one could hypothesize the Garden of Eden as the locus shortly after the Fall from Grace; for the physician, birth; and for the businessman, the first profits. Perhaps this is enough of a list to draw a conclusion. A demarcation between culture and environment is neither arbitrary nor dissolvable, although, under certain conditions, it may be both. The exact relationship between culture and environment is illusive as it moves with equal ease through very different kinds of worlds and realities: the mythic, the symbolic, the historical, the veridical, and the surrealistic. The concepts of culture and environment as well as the relationship between them defy operational definition. Yet, their conrete spatio-temporal manifestation may only be refuted by solopsism.

The dialectic of culture is reflected in three statements: Culture is a human product; culture is an objective reality; man is a product of his culture. A phenomenological study of this dialectic mediates against false consciousness.

Culture is enriched by negative as well as positive symbol structures. Subcultures are a rich source of the negative feedback that keeps a culture from becoming one-dimensional. We need our black sub-cultures. We need our brown, yellow, and red sub-cultures. We need artists, musicians, poets, freaks, and even idlers.

J. Milton Yinger speaks of sub-cultures and contracultures.[17] In my mind, a subculture worthy of the name is already contra. By subculture, then, I do not merely mean a smaller version; I mean a subversion.

Science and technology as the servant of man have brought us to the edge of abundance with a promise of universal satisfaction of vital human needs. For the first time in the history of man, our technological achievements create the potential for freedom from the curse of Adam --- scarcity and the subsequent need for non-creative toil. Man as the servant of science and technology has led us to the brink of disaster, whether the threat comes in the form of a thermo-nuclear holocaust, the gradual poisoning of our environment, or the emmassment of man and the homoginization of culture. In the words of S. P. R. Charter, "How can we uncouple the promise of technology from the threat of technology?"[18]

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[17] J. Milton Yinger, "Contraculture and Subculture," American Sociological Review, Vol. 25 (1960), pp. 625-635.

If it is to be done, we must begin to do it now. We cannot assume that government, science, business, education, or even the revolution will take care of it. I often think that the best place to start is by not doing some things. Why don't we try to limit our activities to only those things that enrich human life?

Is there a way out? Norman O. Brown indicates one way, McLuhan another.[19]

The literary critic and oracle of technology, Marshall McLuhan, has been particularly impressed with the impact of what he calls the information implosion. He is referring to the vast increase in the rate, diversity, and range (both in the sense of content and distance) of information (messages) being communicated to the average member of American society. If he desires it and, often, even when he does not, the average American may be bombarded with a truly incredible number of electronically transmitted sounds and sights. These messages, I might add, can have their origin (by means of communication satellites) from anywhere around the circumference of the earth. On occasion, they may even come from the moon. Thus, it is now quite conceivable --- and the technology already exists --- to place every person on our planet in simultaneous communication with every other person. One must conclude, upon pondering this eventuality, that the globe has indeed imploded. One could hardly invoke the cliche "shrinking globe" in this instance, since the verb "to shrink" clearly implies a process taking place at less than electronic speed.

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[18] S. P. R. Charter, Man on Earth, Contract Edition, Sausalito, California, 1962, pp. 209-218.

[19] Marshall McLuhan, op. cit., War & Peace in the Global Village (With Quentin Fiore), coordinated by Jerome Agel, Bantam Books: New York, 192 pp.

As McLuhan has pointed out, an unfortunate by-product of these advances in communication technology has been an "information overload" --- a condition indigenous to computers, but contagious for men as well. (Actually, computers cope with this indigestion much more effectively than we do.) Information overload results from taking in more information than we are used to or, perhaps, capable of sorting out in a meaningful way. In the terminology of information theory, information overload transforms messages into "noise".

Now, one effective strategy for coping with this state of confusion is to process the complex aggregate of messages, not as a progression of independent entities (our typical mode of thought), but rather as clusters of messages forming recognizable patterns of meaning, a trick first mastered by the symbolist poets and abstract painters. It turns out, further, that this same technique is one that must be taught (excuse me, programmed in-) to a computer in order to get it to discriminate visual symbols (such as the letters of the alphabet) or to recognize and reproduce human speech. In these days of the ever-widening credibility gap (the gap between official statements and actual events), pattern recognition, particularly in a form which takes into account what is missing in the messages, is an increasingly effective technique for approximating truth. Unfortunately we (the older generation) do not find pattern recognition as natural procedure, as our children do.

The electronic communications implosion is not without its implications for social change. The advent of an entire generation to whom it appears normal to be "turned on" to what's happening all over the world, as well as being "hung-up" by more "noise" than "message" in the receiver is a phenomenon that has yet to be completely reckoned with. Clearly, the new electronic technologies lead us to question the validities of national boundaries as marking the limits of human rights, responsibilities, and welfare.

The animal called man has developed highly unusual (one is tempted to say unique) ways of adapting to the environment in which he found himself. He did this not so much by physiological changes, altering the structure of his own organism, but rather by developing extensions of his own bodily equipment in a manner permitting him to change the environment to suit his own needs. This is the origin of technology, of society, and of culture. Can technology solve the problems of technology? In this broad sense of the term, there is little else that can. Still, I am suspicious of hardware solutions to hardware problems. Marshall McLuhan and R. Buckminster Fuller are more optimistic.[20] I would be less pessimistic if we had an entire cultural generation of such global thinkers --- perhaps, if we simply let them grow.

Other ways out --- there is a lot of talk about law and order these days. Social scientists are concerned with law and order, though I prefer to qualify these constructs with the idea of nature, the laws of nature and the order of nature. Notions about law frequently come up in my methodology classes. I usually end up telling my students that the essential difference between the laws of man and the laws of nature (I try to sidestep "natural law" since I have never really understood it) is that you can break the laws of man. When this distinction ceases, all our worries will be over.

I would like to close my remarks with a parable. It is the parable of the lost Shem:[21]

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[20] R. Buckminster Fuller, Ideas and Integrities, Collier Books: Toronto, Ontario, Canada, 1963, 318 pp.

[21] Paul Verden, "The Partridge Dance: A Veridical Fantasy in Four Scenes," Palo Alto, California, 1963.

In talking together, the men of the earth agreed that for each man to keep the Shem in his own mind imposed an unfair and needless burden on him. They decided that the oldest among them should record each man's Shem on a great stone tablet. In this way, they reasoned, when any man sought knowledge of the Shem, he had only to ask the elder scribe to read what had been written in his place on the tablet. The elder praised the soundness and economy of this plan and began to prepare the tablet. When he had recorded each man's Shem on the tablet, the old man thought to himself, "This is far too heavy to carry all the places that I must travel. I will bury it in a cave for safekeeping. When it becomes necessary, I can go to the cave and read what I have written." After the elder had hidden the tablet, a man approached him and asked what had been written in his place on the tablet. Promising to answer him the next day, the elder set out for the mountain where the cave was located. Though he search the entire mountain, he could not find the cave. By the time the Sun was descending behind the mountain, the old scribe realized that he had forgotten the location of the cave. He grew afraid, saying, " . . . I have been a fool! I have only to inscribe a new tablet in order to keep the others from knowing that I have forgotten the place of the cave." Quickly, he began to look for a stone like that from which the other had been made. But, in the darkness, he could find no similar stone. Again, he feared for his life. Then he thought, ". . . I have not been sensible! I need only to tell the others that the first tablet has broken and that it was necessary to copy the inscriptions onto a new tablet." When he started to inscribe the new tablet, however, he found that he was unable to remember anything that he had written on the other tablet. Once more, he was filled with fear. Suddenly, he laughed out loud, "How stupid I have been! The others, too, must have forgotten what I inscribed on the tablet. I will tell them that the Law is written on this new tablet and it will matter little what I inscribe there." When he finished inscribing the tablet, Moses came down from the mountain.

AN APPROACH TOWARD A RATIONAL CLARIFICATION OF ENVIRONMENTAL SCIENCE

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SUMMARY

Modern technology has advanced to such a critical stage that the human species will be extinguished when it either uses up the natural resources (air, water, land, forest, minerals, etc.) or destroys the entire ecological equilibrium. Thousands of unsolved problems plague modern society and many more will be forthcoming. In addition to the impacts of modern technology, the natural hazards (i.e., earthquakes, hurricanes, and epidemics) and the man-made disasters (i.e., war, crime, and drug abuse) still pose a threat to mankind. An evaluation of all disasters with respect to the human value scale, which has not yet been made available, is of paramount importance.

Environmental quality as associated with social values, on the other hand, has been stressed on a national and world-wide basis. An integrated solution of the major environmental issues such as the avoidance of wars of mass destruction, depletion of natural resources, overpopulation, environmental pollutions, and mental distress, is essential for the maintenance of the quality of life, but is presently unavailable. However, responses to these issues remains secondary to the fundamental need for a continuing advance in our ability to improve man's environment.

It is generally agreed among scientists that the solutions to these problems can only be sought through the environmental technology which deals with the interdependence and interactions of man and his environment. It is this belief that has led to the rapid growth of environmental science during the last two decades in federal, local, and state government agencies; private industries; profit and non-profit organizations; as well as educational institutions. Owing to such a rapid growth, tremendous confusion has been introduced by the many so-called environmental sciences groups that have been established with conflicting and often inadequate concepts, goals, and disciplines.

In this article, a clarification is attempted by answering such questions as:

1. What is environmental science?
2. What is essential and why?
3. How does it work?
4. What are the potentials for future development?

This presentation is offered under the following headings: Scope and Classification, Significance of Cyclic Processes, Establishment of an Ecological System, and Future Prospects for Education and Research.

This article by no means intended to encompass all aspects of environmental science, nor does it attempt to establish the only systematic approach. On the contrary, system modeling techniques of environmental science are sadly lacking and desperately needed. It is hoped that this paper will serve as one of the stimuli for future research and development in this vital area.

SCOPE AND CLASSIFICATION

Environmental science deals with the study of the interaction and interdependence of man and his environment. It has grown rapidly during the last few decades through the demand of modern man for his livelihood, comfort, health, and even his life. The ultimate goal of environmental sciences is to maximize the quality of human life and to minimize the hazards of death through natural and man-made sources. It is a science of great complexity, particularly when the total environment of man is considered.* It is an interdisciplinary and applied science rather than a multidisciplinary and basic science.

Strictly speaking this science, by itself, does not exist. The term "environmental science" has been frequently used and abused by its loose application to many interdisciplinary studies. To be sure, not all interdisciplinary studies are environmental studies. An urban study, for example, may not accurately be termed an environmental science unless ALL significant environmental aspects have been incorporated. These urban environmental aspects may be summarized by four main questions:

1. How does the urban physical environment affect city dwellers, vegetation, animals, and properties?

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* A "total environment" considers ALL conceivable and/or measurable factors affecting man as an individual and his society as a whole. These factors may be broadly classified as the physical (air, water, land, and energy), the biological (plant, animal, microorganism, and man as a biological body), the socio-economical (society, politics, and law) and the behavioral (perception process of man and his society). Interdependency and interaction of these factors are basic and logistic considerations in all theories and practices of total environmental science. In principle, of course, the fundamental consideration is the quality of life and the value of human beings.

2. How does the activity of city dwellers affect the total urban environment?
3. What are the degrees of interdependency among such environments as socioeconomical, psychological, and legal?
4. How could the "ecological equilibrium" be most nearly attained?

Specifically, these questions may be elaborated by "air quality over a city," a significant facet of man's environment. In this case the physical environment is the atmosphere and its assorted contaminants. These contaminants, organic and inorganic, are in the forms of solid, liquid, and gaseous particulates. Although they are present in minute quantities in the order of part per million or even part per billion, they are extremely detrimental to men, animals, and plants, as well as damaging to properties. It has been reported that in the United States half of the population is threatened by an air contamination problem of some sort. About 40% of the population is subjected to contamination of major or minor severity.[1] The effects on materials, structures, equipment, and instruments, for example, are breakage, corrosion, deterioration, discoloration, fouling, and pitting. Quantitative evaluation of such effects on urban economy and health are essential, but are presently inadequate.

The background contamination is obviously of natural origin, whereas the major contamination of a city is man-made; this contamination is a result of the normal activity of urban dwellers through the processes of combustion, vaporization, mechanical attrition, and physio-chemical reactions.[2] Obviously, in an urban area the improper location of industrial complexes, the greater population, the increasing volume of vehicles, and the like, would consequently produce more contamination. Particularly in a valley locale where the frequency and intensity of temperature inversion are high, the subsidence of air aloft is frequently strong, and the ventilation is usually low, the contamination is further intensified.

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[1] PHS. 1961. Six Years of Research in Air Pollution, Public Health Service, U.S. Department of Health, Education, and Welfare, 200 pp.

[2] Wang, J. Y. 1968. "Problems of Air Pollution Technology in California" in Proceedings of Conference on Air Pollution in California, San Jose State College, San Jose, California, pp 2-19.

Air contaminants initiated from these sources, dispersed into the atmosphere and degraded or converted into other physical and chemical forms as they are transported from their source to sink or receptor,* are complicated by the presence of a great variety of contaminants, the continuous changes in the weather, and the variations of urban physical and biological boundary conditions. When the socio-economic, socio-political, and group behavioral aspects are taken into account, this complication is further intensified. At present, most of the research and control are restricted to a local and regional basis; ultimately it will be essential on a global basis. The mechanisms of initiation, dispersion, degradation, and dissipation of air contaminants in addition to the social, economical, and political impacts and solutions of air pollution episodes are interrelated and interdependent of a great many disciplinary subjects. A knowledge of the "methods of interaction" among these disciplinary attacks are fragmentary at the present, but vital. For example, little is known of the atmospheric factors that affect the resident time between the source and sink, or of those factors which affect chemical and physical changes of contaminants in the atmosphere.[3] A cooperation of such disciplinary areas as environmental chemistry, micrometeorology, ecology, and material science in the development of "methods of interaction" would be necessary to solve the problem. In short, classical chemical laboratory techniques fail to apply in the natural atmosphere. When the effects of contaminants on the receptor are considered, then such disciplinary areas as environmental health, medicine, physiology, socioeconomics, sociopolitical science, sociopsychology, and surface chemistry would be involved. The collective term for such an interdisciplinary attack is here designated as TOTAL ENVIRONMENTAL SCIENCES.

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*Receptor is an object, alive or inanimate, upon which a contaminant exerts its effect. Human lungs, for example, along with plant leaves and automobile tires are receptors of NO_2, SO_2 and O_3 respectively.

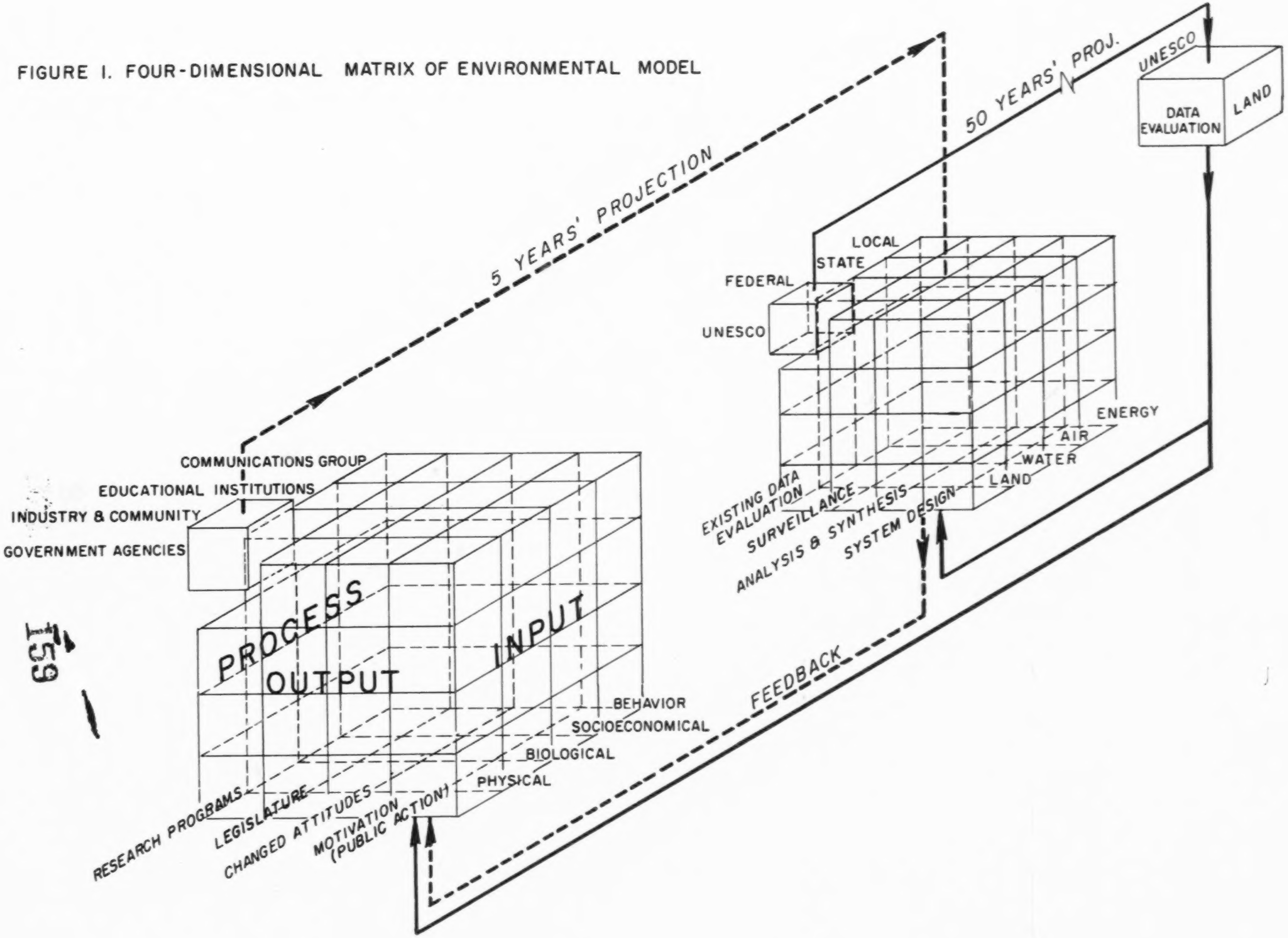
[3] American Chemical Society. 1969. Cleaning Our Environment (The Chemical Basis for Action). American Chemical Society, Washington, D.C., 249 pp.

In order to maintain an "equilibrium" on air quality control it is necessary to recycle the man-made contaminants (a waste product) at the source into a form of useful products (resources) prior to their arrival at the sink or receptor. This has been accomplished experimentally in small scales, but more research is required for an engineering system.

Since the scope of environmental problems is so all-encompassing, a system of classification must be established. The four-dimensional matrix shown in Figure 1 (see page 152) clarifies the broad areas of the subject matter (input), the decision makers (process), and their actions (output). For further elaboration, see the footnote on page 148.

It should be stressed that both natural and man-made environmental hazards must be considered concurrently in the study of environmental problems. Natural environmental disasters such as flood, drought, erosion, forest fire, hurricane, tornado, plague, blizzard, pestilence, earthquake, and volcanic eruption have threatened man for centuries and have not yet been conquered. These hazards not only disturb the balance of nature, but they also destroy life and property. The development of modern technology was furthered in order to conquer hunger and to insure safety from natural hazards. Throughout the United States in 1966, approximately one thousand lives and over a billion dollars

FIGURE I. FOUR-DIMENSIONAL MATRIX OF ENVIRONMENTAL MODEL


5 YEARS' PROJECTION
50 YEARS' PROJ.
UNESCO
DATA EVALUATION
LAND
LOCAL
STATE
FEDERAL
UNESCO
ENERGY
AIR
WATER
LAND
EXISTING DATA EVALUATION
SURVEILLANCE
ANALYSIS & SYNTHESIS
SYSTEM DESIGN
COMMUNICATIONS GROUP
EDUCATIONAL INSTITUTIONS
INDUSTRY & COMMUNITY
GOVERNMENT AGENCIES
PROCESS
OUTPUT
INPUT
BEHAVIOR
SOCIOECONOMICAL
BIOLOGICAL
PHYSICAL
RESEARCH PROGRAMS
LEGISLATURE
CHANGED ATTITUDES
MOTIVATION (PUBLIC ACTION)
FEEDBACK

were lost to weather hazards alone.[4] This involved a loss of livestock and crops, safety in transportation and fisheries, and damage to the construction, power, and energy industries. Environmental disasters are more serious than man-made hazards on a long-range, global basis.

SIGNIFICANCE OF CYCLIC PROCESSES

The imbalance of nature is the most fundamental problem of all environmental problems. An illustration of some of these imbalances is offered in Table 1, according to the type of imbalance, its main cause(s), and the problem areas.

Table 1 An Illustration of Natural Imbalances

Imbalance	Cause	Hazards
ENERGY	Imbalance of crustal forces	Earthquake
	Fluid pressure imbalances	Volcanic eruption
	Gravity and "lubrication" effects	Slide
	Seismic seawaves	Tsunami
	Shock (accoustic) waves	Noise pollution
	Atmospheric pressure imbalance	Hurricane, tornado, dust devil, and other severe storms
HEAT	Excess industrial and solar heatings on water	Thermal pollution
	Atmospheric heatwaves	Foehn, drought
	Atmospheric cold waves and strong radiation-cooling	Freezing damage on vegetation, highways, etc.
	Lightning ignition or man-made fire	Forest fire, brush fire

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[4] BAMS. 1969. "World Weather Program Plan for Fiscal Year 1970," Bulletin of American Meteorological Society, 50 (9): 568-86.

Imbalance	Cause	Problems
POPULATION	High birth rate, low mortality and insufficient occupants' space	Famine, war, social disorders, environmental pollution, etc.
SALT	Irrigation salt deposition	Farm land pollution
	Seawater intrusion	Ground water pollution
	Excess airbourne salts	Air pollution
CHEMICAL	Excess oil in water	Oil pollution
	Excess dissolved organic and inorganic matters and suspended solids	Water pollution
	Excess fertilizer and waste deposits	Land pollution
	Excess toxic chemicals and particulates	Air pollution
WATER	Evapotranspiration exceeds precipitation to the extreme	Drought
	Precipitation exceeds evapotranspiration, runoff and percolation to the extreme	Flood

These imbalances as shown in Table 1 are dynamic systems actively reacting with their environment at various lengths of time to create a new environment or the polluted environment. When such an imbalance disappears, nature will either restore the original environment or create a new set of environmental conditions. Most of the natural processes are cyclic or "reversible," while most of the man-made processes are "irreversible." A cyclic process may be designated as the mechanism which maintains the ecological balance or restores the original environment at a given time.

Some of the imbalance in nature has plagued man since the discovery of fire about a half million years ago. Fire is considered to be the first and greatest human discovery, but it destroyed the natural ecosystem on a local basis.[*] As man settled for farming and, consequently, the establishment of a farm, village, or range, and eventually a city, the balance of nature was further deteriorated. Agricultural practices brought about the localization of living organisms (man, animal, plant, and pest); the accumulation of materials (solid and fluid wastes, pesticides, and chemicals); and the destruction of natural structures (soil profile, soil nutrient, water stream, and sometimes air system). All of these practices deteriorate the natural ecosystem on a regional basis. As modern technology advances, these ecological imbalances are not only intensified, but also spread out to a global basis. It must be concluded that man has NEVER existed in equilibrium with nature since the discovery of fire.

Cyclic processes which govern the ecological balance, for example, are the biological cycle, hydrological cycle, carbon dioxide cycle, nitrogen cycle, and heat cycle. Thus far, the balance of heat and energy in the air, water, land, and living organisms, in addition to the balance of water in the soils, water reservoirs, and plants have been studied on a small scale for short periods of time. Much remains to be studied to understand the cyclic processes of carbon monoxide, oxides of nitrogen, atmospheric ions, and many other unknown organic and inorganic compounds, as well as electromagnetic waves. These studies are vital to the understanding of the mechanisms of the balance of nature.

On the other hand, nature does not always maintain a cyclic process. As shown in Table 2 (see page 156), the geological, pedological, hydrological, atmospherical, biological, and radiation hazards will disrupt the natural ecological system in which human beings are considered as an entity. These disruptions last from a few days to hundreds of years, if not longer. It is therefore suggested that nature does not always coexist with man nor does it always maintain a balance when left undisturbed by man.

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[*] On the contrary, forest fire may promote regeneration, reduce pathogenic fungi, improve soil structure, and remove ectocrimes. Occasionally, it breaks the dormancy of seeds and thus revives new varieties and species of plants

Table 2 Natural Hazards and Environmental Pollution

NATURAL		MAN-MADE	
Sources	Hazards	Sources	Pollutions
1. Energy	lightning strokes lightning glare thunderbolts ultraviolet radiation atomic radiation shockwave	1. Agriculture	waste burning phytotoxicants pesticides (insecticides, herbicides and fungicides) fertilizer spray irrigation salt deposit
2. Atmospheric	hailstorms hurricane tornado thunderstorm dust devil sea spray natural pollution other severe storms	2. Municipal	vehicular emmission traffic congestion sonic booms incineration chimney smoke landfill air pollution scenic pollution
3. Geologic	earthquake volcanic eruption landslide tsunami	3. Industrial	radioactive material stack plumes noise pollution thermal pollution water pollution oil pollution
4. Pedologic	soil compaction soil erosion mudslide frost mound volcanic eruption	4. Domestic (indoor)	detergents cosmetics freon, etc. noises bacteria, fungus, viruses
5. Hydrologic	flood & drought water erosion salt water intrusion frost mount blizzard heavy rain heavy snow icing rime	5. Accidental	fire (forest, brush, building) gas leakage explosions radioactive material leakage traffic accidents
6. Biotic	forest & brush fire bacteria & viruses Insects & disease biological decay physiological drought freezing damage hailstorm damage	6. Military	biological & chemical warfare atomic testing radioactive fallout

In developing an industrial complex or a new city, for example, the cyclic processes break down. The whole concept of a "balance of nature" does not work because it applies to a steady state. There is no steady state as such once man settles in a city in which the input (i.e., resources such as population, vehicles, food and other commodities) and the output (i.e., waste products) form an open rather than a closed system.* As a result of this imbalance, such problems as urban sprawl (e.g., housing shortage and traffic congestion), health hazards (e.g., skin diseases, lead poisoning and high mortality rates in slum areas), environmental pollutions, as well as inadequate and improper waste disposals arise.

We may therefore conclude that man is neither master of the living system nor controller of the physical system. Can we offer incremental solutions of system model designs or innovations for our future survival? Is controlling the birth rate the solution? Abandoning pesticides in agriculture? Reducing the size and/or concentration of cities? Prohibiting the use of automobiles? Can we establish a series of man-made cyclic systems to reinforce the natural ecosystem for survival? There is no single direct answer or simple solution. More research along these lines is essential as the problems are tremendous and very controversial, but highly significant.

ESTABLISHMENT OF AN ECOLOGICAL SYSTEM

In view of the complexity of human activities, at least three steps must be taken toward the establishment of a man-made "closed" system in order to imitate as nearly as possible the natural ecosystem:

1. Coordination of Existing Environmental Information
   Although the available natural and man-made environmental information is fragmentary and often biased, it may be collected, evaluated, and classified. According to the predesigned criteria and procedures, this information is analyzed and transformed into useful forms for interpretation and integration. Through statistical and/or mathematical

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*Most modern industries are open systems, or irreversible processes; whereas the natural ecosystem is mainly a closed system, or a reversible process.

manipulation a series of tentative models (or subsystems) is then developed. This integrated result serves as the first approximation of a solution and is used as a guideline for the successive procedures.

2. Field Survey of Existing Environment

New criteria and procedures for a four-dimensional survey* of the biological and physical are derived from the tentative model in Step 1. The general criteria for the field survey would involve:

- -representativeness (design of sampling techniques)
- -reliability (choice of sensors, exposures, and platform as well as selection of instruments)
- -sensitivity (requirement of response time as well as time and space resolution)
- -accuracy (selection of observers and choice of instruments)
- -efficiency (minimization of surveying time, such as use of moving platform, etc.)
- -economy (costs of installation and maintenance; durability of equipment, including cost of labor)

The general procedures for the survey would be:

- -site selection (specifying conditions for upper, lateral, and lower boundaries for the site)
- -platforms (fixed and/or movable platform)
- -parameters (choice of environmental factors to be observed or measured)
- -instrumentation, if any (including sensor, transmission, storage, and data retrieval)
- -time scale (specifying total length of time and frequency of observation or measurement of field survey)
- -data acquisition (methods of analysis, synthesis, and interpretation)
- -test of validity (verification of findings including calibration of instruments and various statistical tests)

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*This refers to three dimensions of space and one dimension of time. Obviously these surveys will include both observation and measurement.

In practice, of course, a specific, rather than general, set of criteria and procedure must be designed in order to be appropriate. Also, for socioeconomical and human behavioral surveys, the criteria and procedures would be different.

3. System Model Design

By using the short-term field survey data (Step 2) and the long-term historical data (Step 1), a series of system models will be designed. The historical data, which are less desirable than the field survey data, are used as references. Projections of long-term effects, for a period of 5, 10, 20 years or more, must be made. These projections will be feedback to the original model in making modifications. Continual trade-offs will be made until the long-term effects on the orignial model satisfy the preset standards. The end product is the final model which is a closed system.

An illustration of a simple closed-system is in order: Some of the presently available industries such as sewage plants, paper mills, feed manufacturers, fertilizer plants, and steel works, operate under the principle of "recycling," which is a profit subsystem. However, their subsystems have not expanded to a larger system to take care of the entire urban solid wastes. In this proposed system, solid waste should first be transported to a mobile waste carrier in which the great variety of used materials is separated, purified* and compressed into small packages. Each type of waste package will be further channeled by underground conveyor systems to individual waste treating plants for additional treatment and will eventually be converted into useful resources.

Waste paper, as a brief illustration, has been treated by a number of physical and chemical processes and then is converted into its original form. That is, with recycling, paper remains forever as paper. This system may be applied to metal, glassware, fertilizer, and many other substances. When this system is applied, living waste products such as meat, vegetables, and fish will be converted into food for man or feed for animals. Obviously, these waste products cannot be converted back into their original forms. Some waste products such as plastic materials are difficult to convert. On the other hand, some materials cannot be converted at all as, for example, the infant itself considered as a resource and its corpse as the waste; without a revolutionary change in social ethics, these products cannot be converted into feed for animals or food for man.

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*This refers to a physical process of cleaning without undergoing a complex chemical process for purification

When emissions from industrial, agricultural, and domestic sources (see Table 2) are considered, the problem is much more complicated. Once these emissions have been dispersed into the atmosphere, it is very difficult to remove them. Theoretically, if we have enough clean energy sources* we will be able to collect the fluid and solid pollutants from the stack or from the emission pipes and convert them into useful resources. Certainly some research should be directed along these lines. Some meteorologists have suggested the use of the "macrochimney concept"** in order to disperse the pollutants from areas of concentrated pollution. This can be a solution only if (a) the resources of air are unlimited and/or photochemical processes of the upper atmosphere will convert the toxic gases into nontoxic compounds, and (b) the clean energy sources are available.

The ecological imbalance caused by natural hazards (see Table 1) is the rule rather than the exception. When such instances occur, the balance of nature can only be restored through modern environmental technology. Modern medicine, for example, is now capable of curing varieties of diseases which were considered incurable a century ago. Measures for preventing frost, flood, drought, and soil erosion, to name only a few, have achieved various degrees of success. With the over-all view of total environmental sciences these preventive measures would be definitely enhanced.

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*Clean energy sources refer to those such as hydraulic power from waterfalls or tidal waves and solar energy from satellite relay system.

**This refers to a very intense spotty differential heating produced by artificial means. The polluted air is thus drawn into this heated area and dispersed into the upper atmosphere from a very strong updraft.

Of course, many such unsolved problems remain, such as earthquakes, volcanic eruptions, tidal waves, hurricanes, and hailstones. Some of these are predictable, while others are thus far totally unpredictable. Regarding predictability and control, the only hope is, again, the advancement of modern environmental technology.

In conclusion, it is believed that the establishment of a man-made closed engineering system, the prediction and control of natural hazards, and maintenance of quality of life are only possible through the development of total environmental sciences.

FUTURE PROSPECTS FOR EDUCATION AND RESEARCH

Regarding the potentials for development of environmental sciences, education and research are highly significant. In both, a total environmental approach, as mentioned previously, is most fundamental. Of the two aspects, of course, education is the most basic approach.

Education. The training of practitioners and research workers through higher education in the total environmental sciences is essential in realizing the great need for future relevant interdisciplinary scientists to pursue careers in environmental surveying, planning, prediction and control. This applies to community and public education as well as primary and secondary education in a sense of generating a nontechnical and comprehensive knowledge of the environment.

Presently available higher education does not place enough emphasis upon the interaction among the many disciplinary areas. The division of courses in natural sciences (biology, geology, chemistry, etc.) and in social sciences (psychology, sociology, economics, etc.) are artificial rather than natural. The boundary between any two disciplines is difficult to delineate. Often education has adopted traditional multidisciplinary rather than interdisciplinary approaches. A course in general oceanography, for example, may be described by such divisions as chemical, biological, meteorological, and dynamic aspects of the ocean. The interdependence and interaction among them are scarcely touched upon. This is a typical multidisciplinary approach. A full approach to environmental education, however, must penetrate beyond even the interdisciplinary concept in order to provide for the general and essential acceptance of the ultimate responsibility for planning and utilization of these diverse disciplines.

Throughout the United States many primary and secondary schools have initiated the so-called "outdoor education" programs to supplement the general education curriculum and to emphasize the interaction and interdependence of man and his environment. These programs are more or less ecologically oriented and fail to consider the total environmental aspects. Aside from ecology and conservation, a general course in environmental education must be offered in the primary and secondary levels.

For higher levels of education four problem areas should be stressed. These areas and samples of related disciplines are:

> Human and Ecological Environment (e.g. plant and human ecology, agriculture, bioengineering, biomedicine, environmental health, behavioral science, and recreational and leisure sciences)
>
> Physical Environment (e.g. engineering, architecture, physics, chemistry, and earth sciences)
>
> Environmental System (e.g. economics, business management and planning, operational research, mathematics, statistics, and engineering)
>
> Geopolitical and Space Environment (e.g. law, political science, public administration, geography, engineering, and cybernetics)

Since the new divisions of environmental science is merely the beginning, objectives, structure, curriculum, evaluation, and research must be re-defined.

New textbooks, laboratory equipment, techniques of teaching, audio-visual aids, etc., must be prepared in order to meet the requirements.[5] In fact, both instructor and student should be oriented toward the new concept of total environmental aciences.

Research. Prediction and control of man's environment are the main objectives of research in environmental sciences. The ultimate goal is to maximize the quality of human life and to minimize the man-made and natural hazards. By and large, the current research is oriented toward the prediction of natural hazards and the control of man-made pollution. With the exception of flood and drought, little attention has been focused upon the control of natural hazards and the prediction of man-made pollution. Research now in progress on the maximization of life quality, particularly long-term considerations, is far from sufficient.

A brief summary of critical review on current research will be offered first, and then the essence of future research and development on prediction and control of man's total environment will be considered.

Regarding environmental pollution, effects of pollutants on physiology and psychology of life system, damages to properties, and impacts upon the national economy have been recognized. Various schemes for pollution source control have been proposed and employed to a considerable degree. However, these are far from adequate to solve the complex problems. Our presently available knowledge is fragmentary: Effects of pollutants on air, water, and soil are not fully understood; many of the important natural cyclic processes remain unknown; and the intensity and severity of pollution have not been measured accurately. A few of the major problem areas are described below:

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[5] Wang, J. Y. and H. I. Scudder. 1969. Western Center for Environmental Education. Environmental Sciences Institute. 14 pp. (unpublished).

1. Samplings of pollutants in the air, water, land, and bodies of living organisms are spotty and not representative. Time and space distributions of the concentration of these pollutants, therefore, are not known. Continuous recordings of pollutants covering a large geographical area, such as those obtained by the use of remote-sensing instruments, are not available. Significant weather conditions, such as the local wind flow patterns, the micro-atmospheric pressure distribution, the height and intensity of temperature inversions, and the vertical and horizontal distribution of net radiation, have not been recorded on a continual basis over a large geographical area. Perhaps the improvement of satellite techniques in both weather and pollution measurements will prove to be significant.

2. Research on the degrees and types of pollution damages on plants and animals are artificial. Experiments performed thus far (a) use one species of pollutant at a time; (b) measure the effects in a confined artificial environment; and (c) restrict tests to a few species of living organisms which are readily available and easy to control. These findings do not represent occurences in the natural conditions where there are mixed pollutants under unsteady environmental conditions and with the presence of many species and varieties of living organisms.

3. Too many small research projects lead to piece-meal attacks on complicated environmental problems in which interactions among the environmental factors must be taken into consideration. Consequently, their efforts are either too specialized or too restricted, and certainly too costly. Often a new problem may arise due to a failure to consider the entire environmental system. For example, the use of monomolecular film for the suppression of evaporation from a reservior is an important practice in areas where water is expensive; on the other hand, it can be detrimental to the biological balance of the reservior due to the imbalance of oxygen

and carbon dioxide exchange. It will reinforce thermal pollution as the water temperature goes up under the film. In addition, in an area with frequent high wind, intense radiation, and greater vertical temperature and/or water vapor pressure gradients, it is not at all suitable for this practice as the rate at which films are replaced would be too high to be practical.

Some recommendations are offered for improvement of environmental research below:

1. Systematic approach of environmental technology with the consideration of total environmental concept MUST be emphasized.

2. Research on the discovery of new energy sources -- particularly the clean energy source -- as well as the efficiency of energy converting systems would be the most vital single measure in environmental study.

   Evaluation of the existing energy-producing industries must be made with respect to their polluting capabilities, shielding devices, and safety measures as well as methods of conversion.[6]

3. Evaluation of all environmental issues with respect to the human value scale would serve as a guideline for determining the priority of each and for establishing incremental solutions.

4. Research on the effects and mechanisms of total environmental impacts upon the life system, particularly regarding genetic make-up, is to be encouraged. Even if needed, artificial experiments should be minimized.

   In the context of attitudinal changes, studies in environmental pollution relating to the perceptual processes of man are desperately needed.

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[6] Sporn, P. 1969. "Energy for Man and Environmental Protection," Science 166 (3905):555.

5. Studies on the mechanisms of natural cycles and the development of man-made recycling processes are essential to the advancement of environmental research.

6. For long-term considerations, research in environmental education is the basis for strengthening the future man-power in environmental sciences.

7. Last, but not least, consideration of preventative measures dealing with natural hazards must be undertaken. As mentioned previously, much work has been done on the prediction of natural hazards, but far from sufficient work has been concerned with the establishment of systems of control. Even prediction of such hazards as earthquakes, volcanic eruptions and long range weather hazards have been either very poorly done or not done at all.

PANEL DISCUSSION

(For list of Panelists' positions, see page 178)

BARRY:
Our first considerations are: Is there any specific effect that DDT has on the human body? How serious is the problem of developing resistance to pesticides by insect population? These are interrelated and will involve more than one panelist. Is there anyone who would like to speak regarding the effects of DDT in terms of a specific area of the body?

THOMAS:
We know that DDT, as well as the residues of other insecticides and pesticides being used, have a lasting effect and are very stable. They may not be eliminated easily. And it is this which makes a pesticide dangerous aside from its toxicity. After the residues are deposited in the adipose tissues, it may not inflict any harm there once it is arrested by a buffer mileu or atmosphere. But, once it is released or reaches a certain higher toxic concentration, then the difficulties begin. It may then affect any vulnerable or susceptible organ.

BARRY:
I'm not sure that we can arrive at a definite answer, but then I'm not really sure that a firm answer exists on the specific physiological action of DDT in the mammalian body. Dr. Rudd suggested that one effect was its interference with some of the estrogenic hormones which are related to sexual reproduction. This has very definitely been established in some bird populations. As far as large mammals are concerned, pesticide effects remain an item of grave concern. I regret that I did not have a chance to ask Dr. Rudd yesterday about the information that the Department od Fish and Game has to offer concerning the effects of DDT on large mammals, particularly the off-shore mammals. Just a few weeks ago, I was on Ano Nueve Island doing a population count on sea lions and elephant seals. It was tragic to witness the premature abortive deaths of several young pups and we were speculating as to the cause. We were aware of the wide distribution of DDT, but we were unable to establish whether it was the cause of their deaths. We still are not sure, although I suspect that this is a real consequence of DDT.

THOMAS:
May I interject just one additional point? Physiologically, when we speak of toxicity, we refer to certain organs and target tissues and so I would suspect that the cellular level is where pesticide poisoning would have its major effect; that is, enzyme systems inhibition, membrane permeability alteration, etc.

BARRY:
Yes, it's a cellular chemistry level of involvement that is concerned here. It is not like a poison that will burn the skin or that sort of thing.

QUESTION FROM THE FLOOR:
Would you postulate that pesticide poisoning or DDT specifically may have a genetic effect on animals?

THOMAS:
There is a possibility of this occurring. It could be a teratogen; that is, it could cause chromosomal aberrations and consequently might have an effect on the genes that are being transmitted from one generation to the next.

BARRY:
The other important comment I might add in relation to this question concerns the fat or lipid pool----the concept that Dr. Rudd introduced yesterday. As one considers the population of organisms, one looks at a pound of fat; simply forget about the inidvidual organism for a moment and focus on the weight of the total population of animals, each one with a pound of fat; that's a thousand pounds of fat. Obviously, DDT does seek a lipid pool and it is carried there. This has been known for a long time, even in the 1950s.

I remember one of my colleagues was researching on insects when he became aware of the fact that he could feed insect larvae on diets of DDt to a point after which a high percentage would die off. Then he had an evolution pattern on his hands. After a while, however, they would not metamorphose because they had to turn to the stored fats in their larvae in order to metamorphose, and at this time the DDT was released. We did not understand the significance of it at that time, but we're coming closer to it now.

Another significant question is the development of resistance to pesticides by the insect population. Would anyone like to discuss that point?

HARVEY:
There is some evidence I can present only indirectly from the San Juaquin Valley in reference to spraying mosquitoes for controlling equine encephalitis. There was evidence of mosquitoes withstanding a particular insecticide, so the sprayer would shift to another insecticide, and then to still another. In this particular instance, where the spraying program this spring grew in increased proportions due to the large amount of rain and favorable conditions for the mosquitoes, they really have run out of effective insecticides to use. The rate of reproduction has been so great as to produce resistant forms to any of the common insecticides. So, in some specific cases, resistance does build up. That is, by eliminating the susceptible ones, the others breed and if they breed rapidly enough they produce generations that are not susceptible or "resistant."

BARRY:
As a biological relationship, as Dr. Harvey mentioned, it is very likely that an inherited resistance will develop. We know this occurs in bacterial populations with no problems at all.

QUESTION FROM THE FLOOR:
Dr Baum, in reference to the subject now at hand, you have given us some very sound advice. But, what I'm interested in is how you plan to restructure the University of Rhode Island so that it may survive the late Twentieth Century environmental crisis.

BAUM:
In this particular case, our special interest in the environment relates to the ocean. It happens that this is the primary area of our competence and development. There is a great diffusion of concern about the oceans as part of our environment throughout the institution. We offer, for example, a graduate school of oceanography. However, this is not a self-contained unit in which we seek to do all of our research. On the contrary, it is merely a small part of the total program which emcompasses the entire institution. For example, our college of pharmacy is working on problems of developing drugs from the sea; our college of agriculture is concerned with the development of ocean resources; our college of engineering is experimenting in ocean engineering; our school of home economics is very involved with food and nutrition possibilities related to ocean products; and so on. We are taking an approach in this case which focuses upon a particular component in the environment and bringing to bear upon it a broad spectrum of talents scattered throughout a broad group of administrative units within the institution. I think that analogies of this kind need to be developed in other institutions. We must find ways to generate enthusiasm and common concern about important problems -- in this case environmental problems -- that completely cut the disciplinary lines that exist in the educational institutions. We are doing this, and I must say that we are doing it successfully. We are not engaged, at least at this time, in other aspects of the environmental problem, but I would hope that other institutions, either in the marine environment or in other facets of the total environment, would try to adopt that kind of pattern and not allow the preexisting disciplinary and administrative structure to interfere with teaching and research programs.

HARVEY:
It sounds as if your main thrust is toward development of the oceans in some utilitarian way -- for drugs, food, minerals, etc. I think, however, what the question refers to is research to alleviate the possible damages to the ocean.

BAUM:
Well, I did not mention that explicitly, but that is certainly part of the package. Not only is it included in terms of a search for ways and means of

reducing industrial pollution (in our particular case, dealing largely with Naranganser Bay); but quite obviously, if you engage in ocean farming, which is a resource development, you must first be sure that you do not have polluted waters in which to do this farming. It is obviously part of the problem.

QUESTION FROM THE FLOOR:
Then as a college president, do you feel that you will concern yourself just with ocean biology. Is this enough for the University of Rhode Island or is this just a very small beginning in moving toward environmental awareness and research?

BAUM:
I would say that it is a little of both. I think we live in an era in which no single institution can be all things to all men. The scope of knowledge and responsibility and attendant costs are so termendous that no institution can afford to do this sort of thing. We must divide up the problems. To a certain extent, the answer to your question is no. For example, my own field is meteorology and I am quite concerned that the weakest aspect of our ocean program is the failure to do enough work on ocean-air interaction, which is a significant component of the entire environmental problem. I hope that from this nucleus there will be some growth. But, I don't ever expect that the University of Rhode Island or 99% of the universities in this country will be able to mount meaningful research and teaching jobs on the whole spectrum of problems that are involved in man's relationship to his environment.

BARRY:
I think to support his statemen that he has a certain amount of "spin-off" (space-age talk for things that happen which are not anticipated). We have recruited scientific leadership out of this interdisciplinary group of which he speaks at the University of Rhode Island. Hopefully, these people will now turn their talents to similar concerns of our environment here.

I would like to consider another question that is related to this problem. Perhaps Dr. Verden might like to handle this. We have learned of the necessary changes that must be made in attempting to control the environment. I want to ask the panel for opinions regarding the feasibility of world leaders understanding the grave problems you have stressed such as population, pesticide control, and the necessary long-range solutions which must be initiated for our survival as a world community. I recall that you said last night that we are doing our thing, but not necessarily in relation to the real environment.

VERDEN:
As several of the other speakers have stressed, I think that these problems in the final analysis are problems of human attitudes; that is really where

the change must occur. I am personally very suspect of hardware solutions to the problems that hardware has created. That seems to be sort of a vicious cycle. The real problems are very broad and very old problems. Greed seems to be at the heart of a lot of things. It may be that our present cultural forms cannot permit the individual to develop the kinds of attitudes that are needed to make the modifications that will permit him to survive. Very radical changes may be required in our cultural forms before we can bring it about. I have no easy solutions, but I do feel that it is important to remain open to possibilities which at the present seem to border on madness. It is a very difficult situation and we may need some unobvious solutions.

BARRY:
I have another question which Dr. Gates and Dr. Wang may like to consider. Dr. Gates represents one of the repository of American plants for without any question, the collection he has in the Missouri Botanical Garden is outstanding. Dr. Wang is concerned with agriculture and plant production. Famine 1975 says the United States is sending food to over 100 countries. In time of famine, the United States will make a choice of which countries will receive food. How critical is the food shortage within the U.S.? Do either of you have any response to this? We know there have been federal studies in this area.

GATES:
I am no expert in this area, but I would like to make an optimistic comment. I do not think we have seen even the beginning of the potentiality of new food supplies from new plant products. After all, we have tapped the cultivated plant world only, plants that have been available for 3,000 to 5,000 years. We are producing much better wheat, corn, etc. But, in terms of our fundamental knowledge of plant evolution, genetics, bio-chemistry, and modification and potential for finding something new in the plant world, I think one might be pretty far-sighted. Of course, this brings up something else I feel very strongly about: In this intensely emotional response to our whole world crisis, we must be exceedingly cautious not to forget about the thrust of fundamental research. If we involve every one of us too much in these emotional, but interesting, discussions we lose time that could be spent on basic research. We are eroding our very foundation. This is a danger on the national scene. In Washington, the National Science Foundation, where I sit on the Advisory Committee, is attempting to correct this to be sure that there is a strong rise in fundamental research in order to help solve some of these problems.

WANG:
I fully agree with Dr. Gates. As you probably know, we are growing tomatoes in greenhouses on a commercial basis. We have also been using hydrophonics (i.e, growing plants in culture solutions) which has also been commercialized on a small scale. We can also grow plants in air without culture solutions or soil; this is called aeroponics in which the root of the plant hangs enclosed in the moist air and is sprayed regularly with a nutrient solution. With more operational research it will be possible to commercialize this

technique. However, from our ancestors we have inherited a method of growing plants in the soil. This method we might call "pedoponics." The word pedology designates soil sciences.

In addition, the coastal Orientals eat seaweed, jelly fish, bird's nests, sea cockroaches, and tiger lily flowers. There are tremendous amounts of jelly fish and seaweed along the coast of California. I understand that the native Californians do not use them. What a waste! This is a matter of oreintating attitudes toward one's diet. Also, Dr. Kahn, of the Cornell University Experimenting Station, in his study entitled "Morphactions Destroy Plant Responses to Gravity and Light," indicated that seeds of lettuce, oats, and timothy, when treated with morphactin compounds IT 3233 and IT 3456, produce seedlings in which phototropism and geotropism are destroyed. This merely means that with chemical treatment the root will resist the gravitational force and the leaves and shoots will resist light. I have seen Dr. Werner of Lincoln, Nebraska, grow his potatoes up-right like an apple tree with the tubers hanging in the air instead of buried underground. We can do this easily. What I would like to stress here is that through modern technology we can change the natural processes and produce more crops and animals for food sources.

We know that in the United States only 2% of the land has been urbanized (the other 97 or 98% is still open to use in various ways), and in California only 3% has been urbanized. The microclimate and soil association in some mountainous regions are, for example, suitable for certain domestic animals and cereals and horticultural crops. The Russians have a saying that plants under snow are just as comfortable as an old man under a fur coat. With the development of vernalization we can extend our growing season in cold regions.

Unfortunately, Peter Raven is not here this afternoon. He would be able to offer a very strong agrument to the contrary. Some of the population experts claim that we shall be plagued with famine by 1975, if not earlier. I only hope that I can live until then.

BARRY:
I am sure that many of you are aware that one of the national networks presented a program recently called "Poverty, USA" and they generated a lot of film footage and made a public presentation depicting some miserbale conditions on the American scene. This program has been challenged by the United States government, so I do not know exactly what its status is. We cannot answer your question because it simply has not been a central concern in America. I recently saw what I thought was a very imaginative presentation by a socialist. He asserted that we should have a continuous social inventory of the state of affairs of the human condition, just as we have physical inventories of what is available in our plants.

HARVEY:
I cannot match Peter Raven's eloquence, but I think we are veering off and asking an odd question: Is it technologically POSSIBLE to feed 5 billion people on this earth or 20 billion? The first question which should be answered is, do we WANT to have that many people on this earth? Dr. Baum

suggested that the ABM question is a technological one. I think, it is the same as engineers wishing to construct dams and bridges on rivers in various parts of the world; we must first ask, "Do we want them?" rather than "Can it be done?" or "Is it hypothetically possible to do this?" As you point out, Dr. Wang, we have been growing crops by hydroponics for a number of years. But are we producing per capita more food in the world than we were ten years ago? I think that evidence indicates to the contrary.

THOMAS:
Also, I think that we should not lose sight of the very important fact that on one hand man is attempting to improve the methods of supplying food and on the other hand he is destroying food. I refer to articles which appear in the newspapers regarding the defoliation of large acreages. You know, it affects me as a human being. Soil that becomes somewhat sterile for a period of time will not produce food. I wonder what the balance is; which side is outdoing the other? Are our new techniques in food production outweighing our destruction of the capacity to produce food?

BARRY:
One of the central questions, I think, that faces us all as we look at our technological capacity is that we say, "If it is possible, it should be done." This is not necessarily true. We need more criteria.

ZSCHEILE:
May I add something? One of the problems with hydroponics is, of course, the cost of the food which is produced. Although you may increase the productivity of an area by using hydroponics, you also increase the cost enormously. What is needed is a crop which is lower in cost than those existing today; crops which take less water,less energy, less human resources, less land to produce more food. Of course, we have such technology fairly well developed in the United States, namely the large-scale production of algae. Since approximately two-thirds of our land is now devoted to protein production and still half of our citizens do not get adequate amounts of protein, I feel that greater emphasis should be placed upon large-scale algae production. This is a two-edged sword: Algae can be grown most productively on organic (animal) waste so that the pollution problem can be alleviated while the protein level is increased. I do not mean that our citizens should eat algae produced on waste, but we could feed this algae to milk cows and produce other proteins in this manner. Algae is the cheapest source of protein currently available in the United States, and perhaps in the world.

BARRY:
One other question that has arisen is what practices will be implemented as a result of this conference? We have held the conference, we have opened it to the public with national publicity. With national leadership, it has attracted national attendance. But, I am not sure that we are ready to answer questions on specific actions; perhaps the proper action is each individual participating in the conference and acquiring the information

that this conference has offered. How will each of you act with this information and what will you do with it? The conference will not have been effective if you have merely found it interesting but neglect to integrate it into your own life pattern.

Another question relates to this comes to mind. I am not certain whether we have any specific material in California public school curriculum that relates to environmental pollution. I am sure that we do include it in terms of general biology, but I do not know about more specific environmental education. Does anyone have more accurate information regarding this?

GATES:
May I comment on the previous topic? You asked what we can do. Of course, there is much public response and concern over environmental problems, but let me mention something else I think we should do -- and I have been suggesting this on the national scene so maybe some day it will come about.

In World War II, in Operations Research, we learned to work out the strategy of attack and the strategy of defense and we set up corporations like the Rand Corporation to advise the Deaprtment of Defense and the Air Force on these strategies. This proved to be very effective. After the war, the Operations Research technique was adopted very effectively to solve problems in traffic control and directing traffic flow in large cities. Now we need corporations and groups working on the strategy of living to solve these massive problems of environmental balances. We do not know the answers and we are only getting a glimpse of the proper interpretation because only a few scholars have worked on the problem. This is certainly not what we want to depend upon for our survival. It is my personal opinion that our government is going to have to set up some very large groups -- corporations, academia, or whatever -- to grope out an effective strategy of living. If there is going to be an oxygen shortage because of pollution of the phytoplankton, for gosh sakes somebody had better discover this just as soon as possible! If we are going to use the tropical forested areas, let's not let them go by default. Let's plan the strategy and at least make a rationale for our choice. This is one of the actions I think we should take.

BARRY:
I have another agricultural question: Large single-crop farming has an adverse effect upon this environment in terms of increasing insect concentration, use of pesticides, soil nutrient depreciation, etc. Has any research been done on practicality and plant quality when multi-crop farming has been used either in controlled environments or as open crops? Has multi-crop farming been tried anywhere on a large scale, and if so, has it met with any success? Dr. Zscheile, what would be your reaction to this?

ZSCHEILE:
I wonder what is meant by multi-crop? Several crops at the same time on the same land or successive crops on the same land?

BARRY:
Several crops at the same time.

ZSCHEILE:
Well, you will see such things as orchards with grapes growing between the trees; in some areas you will see row crops in orchards areas and sometimes in vineyards. That is to say, short-term crops growing amidst long-term crops are not uncommon.

QUESTION FROM THE FLOOR:
Was the question asked in the context of ecological diversity in contrast to the mono-culture where one could get wiped-out by one or all of the environmental factors?

BARRY:
Yes, this happens in mono-culture.

ZSCHEILE:
Well, this has been recognized for a long time as good agricultural practice to rotate crops and to give insects from one crop time to die off before planting that same crop again. Such programs as this have been used for quite a while in agriculture.

BARRY:
So long, in fact, that you can go back and read Virgil's Georgics and find that he had sound advice and council to offer on this very same subject. I suppose this is one of the unfortunate things; we have been aware of many of our problems for a long time, but we have failed to act upon them.

QUESTION FROM THE FLOOR:
Are there any species of crops which can survive in a polluted environment?

ZSCHEILE:
This is a question that could be very nicely studied. The population-genetics people, for example, have a related problem. They plant large populations of mixed varieties and over a long period of time see which survive. Such experiments are being done in that field, particularly with cereals.

BARRY:
Let me conclude with one final question which is of a general nature, but which also relates to action. Do you forsee the possibility of a fourth branch of government in the form of science agencies to advise and formulate legislation which relate to science (i.e., city planning, ecological benefits, harmful effects from planning, etc.)? Perhaps we could just speak on this

issue and then close the conference.

HARVEY:
How large of a government unit are you considering?

BARRY:
Let us use city planning as an example. We could study it at all levels. I know that there has been talk of implementing this at the federal level. Should there be a Secretary of Science or that sort of thing?

HARVEY:
I can only speak of my own experience with the Bay Conservation and Development Commission which has employed me as an ecology consultant for the past three and one-half years. I think that there is some hope that agencies will do this on an individual basis, but I think you imply more in your question than just that. I will yield to Dr. Baum who I think has had some first-hand experience.

BAUM:
I am not sure what is meant by a fourth branch of government. It may well be that in the environmental control area we will need some independent agencies comparable to the FCC in the communications field, for example, or the SCC in the securities exchange field and so on. Perhaps that kind of regulatory body will indeed be necessary. _If_ that is what is meant by a fourth branch of the government. I think that is a distinct possibility and it may even be highly desirable. On the other hand, if by a fourth branch you mean that scientists should somehow become rulers, I would, as a scientist, be very much opposed to it.

BARRY:
It is an issue that has been very widely discussed on the national level. Should there be a Secretary of Science? How can scientists organize to become an effective influence on the public sector? There have been a number of experiments and I think that they have been effective.

There are more comments and we could go on; however, hopefully, the concern which each of you have expressed will continue after the conference ends. I was asked how many attended the conference. We had at least 600 registrants and there were many others who did not register. I believe the work of the speakers has been effective.

On behalf of the Environmental Sciences Institute and the School of Natural Science and Mathematics of San Jose State College I will bring the program to a close. Let me now thank Dr. Wang, Dr. Harvey, Dr. Brooks, the Executive Committee, the many students and faculty members who worked with us, and all of you participating for making this a very successful program.

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